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THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE.

By Capt. J. ERICSSON.

From "Nature."

Perre Secchi, in the second edition of "Le Soleil," published at Paris, 1875, again calls attention to the result of his early investigations of the force of radiation emanating from different regions of the sun's surface, reiterating without modification his former opinions regarding the absorption of the radiant heat by the solar atmosphere. It will be well to bear in mind that the plan adopted by the Italian physicist in his original researches, on which his present opinion is based, was that of projecting the sun's image on a screen, and then, by means of thermopiles, measuring the temperature at different points. The serious defects inseparable from this method of measuring the intensity of the radiant heat I need not point out, nor will it be necessary to urge that a correct determination of the energy transmitted calls for direct observation of the temperature produced by the rays projected towards the earth. Accordingly, on taking up that branch of my investigations of radiant heat which relates to the difference of intensity transmitted from different parts of the sun's surface, I adopted the method of *direct* observation. The progress was slow at the beginning, owing to the necessity of constructing an astronomical apparatus of unusual dimensions, but having devised means which rendered the employment of any desirable focal length practicable, the work has progressed rapidly. An instrument of 17.7 metres (58 feet) focal length, erected to conduct preliminary experiments, has proved so satisfactory that the construction of one of 30 metres focal length, which I supposed to be necessary, has been dispensed with. Considering that the apparent diameter of the sun at a distance of 17.7 metre's from the observer's eye is 162.4 millimetres even when the earth is in aphelion, the efficacy of the instrument employed might have been anticipated. The nature of the device will be readily comprehended by the following explanation :—Suppose a telescopic tube 17.7 metres long, 1 metre in diameter, devoid of object-glass and lenses, and mounted equatorially, to be closed at both ends by metallic plates or diaphragms, at right angles to the telescopic axis. Suppose the diaphragm at the upper end to be perforated with two circular apertures 200 millimetres in diameter, situated one above the other in the vertical line, 360

millimetres from centre to centre; and suppose a third circular perforation whose area is one-fifth of the apparent area of the solar disc, viz. 72.6 millimetres diameter, to be made on either side of the vertical line. Suppose, lastly, that the diaphragm which closes the lower end of the tube be perforated with three small apertures 6 millimetres in diameter, whose centres correspond exactly with the centres of the three large perforations in the upper diaphragm. The tube being then directed towards the sun, and the actinometers applied below the three small apertures in the lower diaphragm, it will be evident that two of these instruments will, after due exposure to a clear sun, indicate maximum solar intensity, say 35° C., while the actinometer applied in line with the perforation whose area is one-fifth of the apparent area of the solar disc, will indicate $\frac{35}{5}=7°$ C., unless the central portion of the solar disc radiates more powerfully towards the earth than the rest, in which case a higher intensity than 7° C. will be indicated by the actinometer referred to. It will be readily understood that the solar rays entering through the perforations at the upper end of the tube, converge at the lower end and pass through the small perforations, causing maximum indication of the focal actinometers as stated. Now, suppose that a circular plate, the area of which is exactly four-fifth of the apparent area of the sun, viz. 145.2 millimetres diameter, be inserted concentrically in either of the two large perforations of the diaphragm at the top of the telescopic tube. The apparent diameter of the sun being as before stated 162.4 millimetres, it will be perceived that the inserted plate will only partially exclude the solar radiation, and that the rays from a zone 1′ 42″ wide will pass outside the said plate, converging in the form of a hollow cone at the lower end of the tube, and there enter the respective actinometer. The indication of the latter will then show the thermal energy transmitted by radiation from a zone whose mean width extends 49″ from the sun's border. It should be particularly observed that the three focal actinometers employed will be acted upon *simultaneously* by the converged rays, (1) from the entire area of the solar disc, (2) from a *central* region containing one-fifth of the area, and (3) from a *zone* at the border containing also one-fifth of the area of the solar disc. It is scarcely necessary to point out that an accurate comparison of the intensity of the radiant heat emanating from the central part and from the sun's border calls for *simultaneous* observation, in order to avoid the errors resulting from change of zenith distance and variation of atmospheric absorption during the investigation. The great advantage of obtaining also a simultaneous indication of the intensity transmitted by radiation from the entire solar disc is self-evident, since this indication serves as an effectual check on the observed intensities emanating from the *centre* and from the *border*. The latter obviously must be less, while the former must be greater, for a given area, than the indication of the focal actinometer which receives the radiation of the entire solar disc.

The foregoing demonstration, based on hypothesis, having established the possibility of ascertaining by direct observation the temperature produced by the rays projected from certain parts of the solar surface, let us now examine the means actually employed. An observer on the 40th deg. latitude, stationed on the north side of a building 28 metres high pointing east and west, can just see the sun pass the meridian, during the summer solstice, if he occupies a position about 8 metres from such building. Now, if an opaque screen perforated by a circular opening 313 millimetres in diameter be placed on the top of the supposed building, the entire solar disc may be seen through the same, provided it faces the sun at right angles. But if perforation in the said screen be 140 millimetres in diameter, only one-fifth of the area of the solar disc will be seen. And if the screen be removed and a circular plate 280 millimetres in diameter put in its place, the observer, ranging himself in line with the plate and the sun's centre, can only see a narrow border 1′ 42″ of the solar disc. Obviously the screen placed on the top of the building might be perforated like the upper diaphragm of the supposed telescopic tube, and a plate resembling the lower diaphragm, secured by appropriate

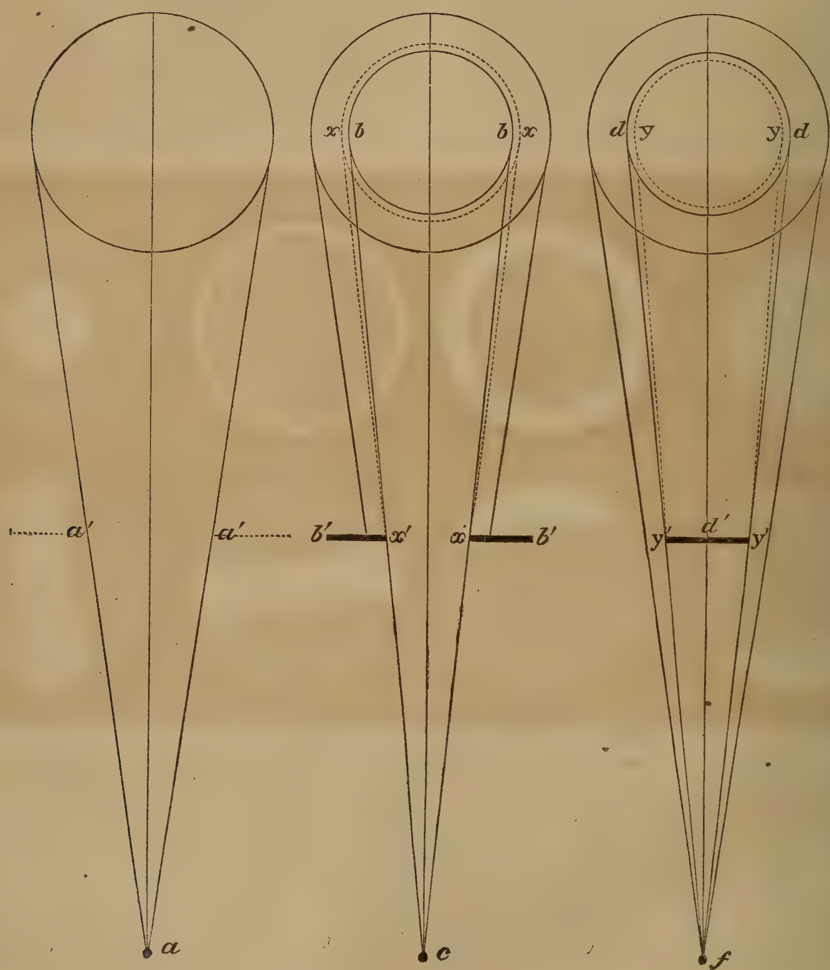
means near the ground, might be made to support the focal actinometers in such a manner that their axes pass through the centres of the perforations of the screen above the building. It is hardly necessary to state that the plate supporting the actinometers should be attached to some mechanism capable of imparting to it a parallactic movement, during the observation, corresponding with the sun's declination and the earth's diurnal motion; and, that some adequate mechanism should be employed for regulating the position of the perforated screen and adjusting the focal distance in accordance with the change of the subtended angle consequent on the varying distance from the sun. It will be evident that since the first-named mechanism rests on the ground, while the latter is secured to a massive building, far greater steadiness will be attained by our simple and comparatively inexpensive device, than by employing a telescopic tube of the most perfect construction mounted equatorially.

With reference to the influence of diffraction, it should be stated that before determining the size of the screens intended to shut out certain parts of the solar disc during the investigation, the amount of inflection of the sun's rays was carefully ascertained. Two distinct methods were adopted: (1) measuring the additional amount of heat transmitted to the focal thermometers in consequence of the inflection of the rays; (2) increasing the *theoretical* size of the screens until the effect of inflection was overcome and the luminous rays completely excluded. Regarding the first-named method of ascertaining the diffraction, it is important to mention that the temperature transmitted to the focal actinometers by the inflected radiation which passes outside of the theoretically determined screens is not proportionate to the inflection ascertained by the process of enlargement referred to. This circumstance at first rendered the investigation somewhat complicated, but it soon became evident that the discrepancy is caused by the comparatively small inflection of the *invisible* heat rays. It will be seen presently that the radiant heat which passes outside of the screens in consequence of diffraction is considerably less than that which would be transmitted to the focal actinometers if the calorific rays were subjected to an amount of inflection corresponding with the enlargement of the screens beyond the theoretical dimensions necessary to exclude the luminous rays.

Let us first consider the method of ascertaining the inflection of the rays by measuring the additional amount of heat transmitted to the focal actinometers. Fig. 1, see illustration, represents the solar disc, a being the focal actinometer exposed to the converged rays, a' a' representing an imaginary plane situated 17.7 metres from a, at which distance the section of the pencil of converging rays will be 162.4 millimetres in diameter, provided the earth is near aphelion. Fig. 2 also represents the solar disc, and c the actinometer exposed to the converged rays; but a perforated screen b' b' is interposed, the perforation being of such a size that only the rays projected by the central half of the solar disc (indicated by the circle b b) pass through the same and reach the focal actinometer. The screen b' b' being situated 17.7 metres from c when the earth is in the position before referred to, the said perforation must be 114.83 millimetres in diameter, in order that the lines $b\,x'\,c$ may be straight. Fig. 3 likewise represents the solar disc, its area being divided in two concentric halves by the circle d d; but in place of a perforated screen, an opaque circular screen d' is introduced at the same distance from the focal actinometer as in Fig. 2; consequently the lines $d\,y'\,f$ will be straight. Now, if the actinometers a, c *and* f be exposed to the converged solar radiation *simultaneously and during an equal interval of time*, c and f receiving the heat from one half of the solar disc (the former from the central and the latter from the surrounding half), the temperatures of c and f added together should correspond exactly with the temperature transmitted from the entire solar disc to a. Observation, however, shows that the temperatures of c and f together is 0.091 greater than the temperature imparted to a. Hence an increase of temperature of nearly one-eleventh is produced by the inflection of the calorific rays, one-half being the result of the bending of the rays within the perforation of the screen b' b', the other half re-

sulting from the bending outside of the screen d'. The increment of temperature being thus known, the degree of inflection may be easily determined by drawing a circle $x\,x$ round the circle $b\,b$, covering an additional area of $\frac{0.091}{2}$ $=0.0455$; and by inscribing a circle $y\,y$ within $d\,d$, covering an area of 0.0455 less than the area of $d\,d$. It will be perceived on reflection that $x\,x'\,b$ represents the angle of inflection of the calorific rays within the perforation of the screen $b'\,b'$, and $d\,y, y$ represents the angle of inflection outside of the screen d'. Demonstration shows that the former angle

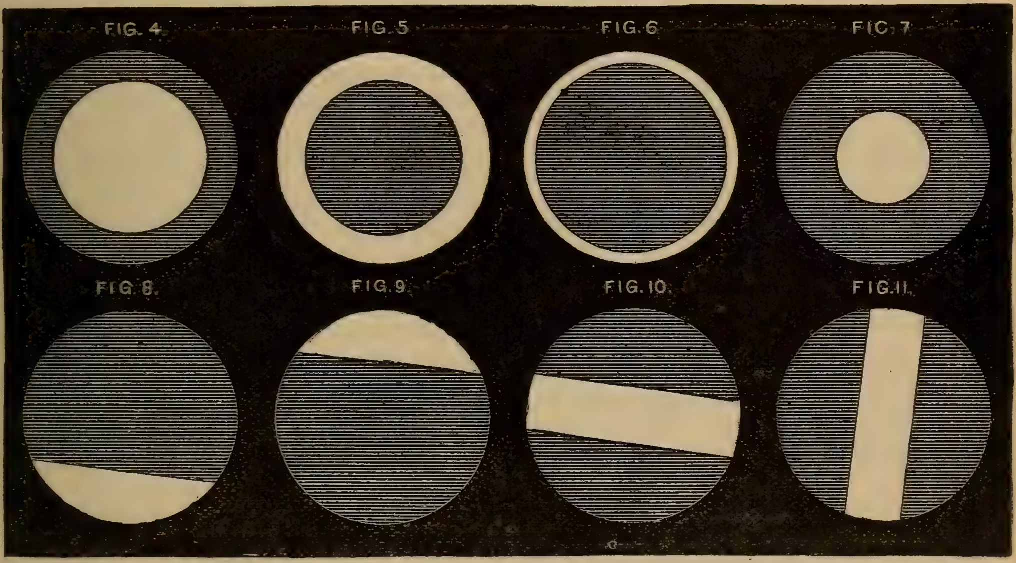
FIG. 1. FIG. 2. FIG. 3.



measures 14″.57, while the latter measures 14″.86, the mean being 14″.71. Having thus determined the inflection resulting from invisible radiation, let us now ascertain the inflection of the luminous rays. As before stated, the apparent diameter of the sun at a distance of 17.7 metres from a given point is 162.4 millimetres when the luminary is furthest from the earth. Now our investigation shows that a screen 167 millimetres in diameter hardly suffices to exclude the luminous rays; hence their inflection amounts to $\frac{167-162.4}{2}=2.3$ millimetres in a distance of 17.7 metres.

Their angle of inflection will therefore be 26″.81, against 14″.71 for the dark rays. We have thus incidentally established the fact that the inflection of the luminous and calorific rays differs nearly in the same proportion as the calorific energies of the visible and invisible portions of the solar spectrum.

Our space not admitting of a detailed account of the result of the investigation, the leading points only will be presented. The observations have all been made at noon, the duration of the exposure to the sun having been limited to seven minutes, during which period the actinometers are moved, by the parallactic mechanism, through a distance of 55 centimetres, from west to east. The intensity of the radiant heat imparted to the actinometers has been recorded by the observers at the termination of the fourth, fifth, sixth and seventh minute, the exact moment for reading off being indicated by a chronograph. The relative intensities transmitted by radiation from the centre and from the border of the solar disc, first claim our attention. Fig. 6 represents the solar disc covered by a circular screen 145.25 millimetres in diameter, excluding the rays excepting from a narrow zone, the mean width of which is situated 49″ from the border of the photosphere. Fig. 7 shows a screen excluding the solar rays excepting from the central portion, *the area of which is precisely equal to the area of the narrow zone* in Fig. 6. The following table shows the intensities transmitted to the actinometers during an observation, August 25, 1875, the radiation from the solar disc being then excluded in the manner shown in Figs. 6 and 7:



Time.	Central portion. Cent.	Border. Cent.	Rate of difference.
4′	3°.28	2°.19	$\frac{2.19}{3.28}=0.667$
5′	3°.56	2°.37	$\frac{2.37}{3.56}=0.665$
6′	3°.73	2°.49	$\frac{2.49}{3.73}=0.667$
7′	3°.88	2°.60	$\frac{2.60}{3.88}=0.669$
			Mean=0.667

It should be particularly observed that this table records the result of four distinct observations; nor should it be overlooked that although the intensities vary greatly for each observation in consequence of the continued exposure to the sun, yet the rates showing the difference of the intensity of the rays transmitted from the border, inserted in the last column, is practically the same for each observation, the discrepancy between the highest and the lowest rate

being only 0.004.* Persons practically acquainted with the difficulty of ascertaining the intensity of solar radiation will be surprised at the exactness and consistency of the indications of our actinometers. This desirable exactness has been attained by surrounding the actinometers with water-jackets, which communicate with each other by connecting pipes, through which a steady stream of water is circulated. By this expedient the chambers containing the bulbs of the several thermometers are maintained with critical nicety at equal temperature, an inexorable condition when the object is to determine differential temperature with great exactness. Apart from this, the chambers which contain the bulbs of the thermometers are air-tight, the radiant heat being admitted through a small aperture at the top of the chamber, covered by a thin crystal.

Referring to the preceding table, it will be seen that the intensity transmitted by radiation from the sun's border, represented in Fig. 6, is 0.667 of the intensity transmitted from the central region represented in Fig. 7, the area of each being precisely alike. From the stated intensity must be deducted the heat imparted to the actinometer by the inflection of the calorific rays. The circumference of the perforation of the screen shown in Fig. 7 being exactly one-half of the circumference of the screen in Fig. 6, while the central region radiates more powerfully than the border, fully one-half of the inflected radiation from the border will be balanced by the inflected radiation emanating from the central region. Agreeable to the previous demonstration relating to Figs. 2 and 3, it will be seen that the unbalanced inflection amounts to 0.029 ; hence the radiation transmitted from the border zone will be $0.667-0.029=0.638$ of the intensity of radiation transmitted from the central region. We have thus shown by a reliable method that the intensity of the rays directed towards the earth from the border zone suffers a diminution of $1.000-0.638=0.362$ of the intensity of the radiation emanating from the central region. But the mean depth of the solar atmosphere of the border zone, in the direction of the earth, is 2.551 greater than the vertical depth, while the mean depth over the central region referred to is only 0.036 greater than the vertical depth of the solar atmosphere. Consequently, if we accept the assumption that the retardation is as the depth, the absorption by the solar atmosphere cannot exceed $\frac{0.362}{2.551-0.036}=0.144$ of the radiant heat emanating from the photosphere.* It will be found on referring to the revised edition of "Le Soleil," vol. i., page 212, that Père Secchi makes the following statements regarding the absorptive power of the solar atmosphere. (1) "At the centre of the disc, that is to say perpendicularly to the surface of the photosphere, the absorption arrests about $\frac{2}{3}$ or more exactly $\frac{62}{100}$ of the total force." (2) "The total action of the absorbing envelope on the hemisphere visible from the sun is so great that it allows only $\frac{12}{100}$ of the total radiation to pass, the remainder, namely, $\frac{88}{100}$ being absorbed." It is unnecessary to criticise these figures presented by the Roman astronomer, as a cursory inspection of our table and diagrams is sufficient to show the fallacy of his computations. Apart from determining the absorptive power of the solar atmosphere, the most important problem which may be solved by accurately measuring the intensity of the radiation emanating from various parts of the disc, is that relating to the sun's emissive power in different directions. In order to decide this question, I have adopted the plan of measuring the energy of the radiant heat transmitted from zones crossing the solar disc at right angles, as shown in Figs. 10 and 11. Should it be found that our actinometers are equally affected by the radiation from these zones, each of which occupies an arc of 30 deg. containing one-third of the area of the disc, the inference will be irresistible that the sun

* All my instruments for measuring radiant heat have been graduated to the Fahrenheit scale; which practically is more exact than the Centigrade, owing to its finer divisions. For the benefit of the Continental readers of *Nature*, and in order to satisfy English and American advocates of the course Centigrade, the observed temperatures have been reduced to that scale before being entered in our tables.

* In the first edition of "Le Soleil," p. 264, the author assumes that the absorption of the calorific rays by the atmosphere "augments in proportion to the secant of the zenith distance;" in other words, as the depth of the atmosphere penetrated from the rays.

emits heat of equal intensity in all directions. It should be borne in mind that, agreeable to our method, the radiations from these zones are observed simultaneously. The arrangement exhibited in Figs. 10 and 11 hardly needs explanation. Referring to Fig. 10, it will be seen that two segmental screens are employed excluding the radiant heat, excepting from the zone, which is parallel with the sun's equator. Similar screens are employed (see Fig. 11) for excluding the rays excepting from the zone parallel with the sun's polar axis. The curvatures of the segmental screens, it should be observed, have been struck to a radius of ninety millimetres, in order to cut off effectually the inflected radiation from the sun's border. Obviously diffraction has not called for any correction of our observations relating to this part of the investigation, since the inflected radiation from the equatorial zone exactly balances the inflected radiation from the polar zone. It only remains to be stated that repeated observations show that the radiant energies transmitted to the actinometers from the two zones are identical. The result of observations relating to the radiation emanating from the polar regions, represented in Figs. 8 and 9, together with other observations, will be discussed in future communications.

ARCS OF ADJUSTMENT—FOR FLATTENING THE EXTREMITIES OF RAILROAD CURVES.

By Mr. N. B. PUTNAM.

Written for Van Nostrand's Engineering Magazine.

A railway car moving on a curve is, at every point of its path, acted upon by a normal force, which tends to drive the car from the rails and away from the centre. This force, called centrifugal force, is $\frac{mv^2}{r}$ Gaussian pound units, and is equal to the weight of $\frac{mv^2}{gr}$ lbs., m being the mass of the car; v its velocity in feet per second; r the radius of curvature of the path, at any given point, in feet; and $g=32.2$ the numerical value of the force of gravity on unit mass. This force bears to the weight of the car the proportion of $\frac{v^2}{gr}:1$; and this is the ratio which the elevation of the outer rail at the given point, or cant must bear to the gauge, in order that the action of gravity in forcing the car down the inclined plane shall equal and oppose centrifugal force.

In circular curves r is constant, and consequently

$$\text{cant}=\text{gauge}\times\frac{v^2}{32.2\,r}$$

is constant throughout the whole extent of the curve. When the velocity is given in miles per hour$=$V, $v=\frac{5280}{3600}\text{V}$ and cant$=$gauge$\times\frac{\text{V}}{15\,r}$ nearly.

As it is impossible to adjust the cant for all speeds, it is customary to adopt the highest ordinary velocity for the value of V.

Let $\text{V}=40$, and let $4'.7$ be the gauge, then cant$=4.7\,\frac{1600}{15\,r}=\frac{500}{r}$ nearly.

In circular curves $r=\frac{100}{\text{Sin D}^\circ}=\frac{100}{\text{D}\sin 1^\circ}$

$\therefore$ cant$=5$. D. sin $1^\circ=.088$ D nearly, in which D is the degree of the curve. Thus the cant for $\text{V}=40$ is about $1''$ per degree of curve on a $4'\ 8\frac{1}{2}''$ gauge.

With V constant cant $\propto\frac{1}{r}$, and in order that the formula may hold good for all parts of a curve, every change of cant should be accompanied by a change of curvature, and since changes of cant must be gradual, changes of curvature should be gradual also. The simplest law in accordance with which we should desire the cant to vary, is that the cant at different points should be proportional to the distance of these points from the beginning of the curve; in other

words, the level of the outer rail should change by a uniform gradient; then in passing from a straight line where the value of cant is zero, to a circular curve or radius r, where the cant is c, the straight line and circle should be connected by a curve tangent to, both which commences with an infinite radius of curvature or curvature$=o$, which terminate with a radius of curvature$=r$, and which at any intermediate point has a curvature directly or a radius of curvature inversely proportional to the distance of the point from the commencement of the curve.

Froude's "curve of adjustment" is a close approximation to such a curve. According to Mr. Froude, the length of the curve of adjustment should be not less than 300 feet for every foot of change of cant.

Taking the gradient of the outer rail as 1 : 300, and applying this curve to circles of 1, $1\frac{1}{2}$, 2 degrees, we have for shift 0.005, 0.017, 0.04 ft.

The value for shift varying as D^3.

[See Rankine's Civil Engineering, p. 642, eqs. (6) and (7).]

Thus the shift for a 2° curve is less than $\frac{1}{2}$ inch, and the tangent, curve of adjustment and circular curve, practically coincide with the tangent and original curve.

We assume then that, in the transition from a tangent line to a curve, whose degree is not greater than 2 or from a D° curve to a D'° curve where $D \sim D' \leq 2$, the change of cant may be "humored in" with a degree of accuracy sufficient for railroad work.

Let A A A′ (Fig. 1) be a circular rail-

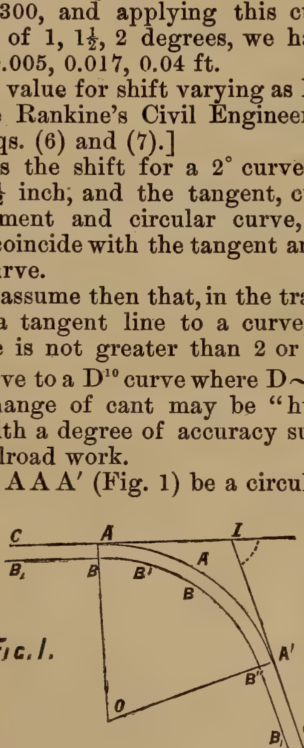


Fig. 1.

road curve, of radius R, connecting the tangent lines C A I, I A′ C, A and A′ being the tangent points; the common distance of these points from I is

$$AI = A'I = R \tan \tfrac{1}{2} I.$$

Let B B B″ be a curve parallel to A A A′, and at a distance A B from it; $B_1 B_1 B'' B_1$ the tangents to B B B″ at B and B″ are then parallel to C A and C A′ respectively.

A B is called the shift of the curve A A A′ or "the shift," and B B B″, the shifted curve. $B_1 B, B'' B_1$ are called auxiliary tangents.

When the radius of the curve B B B″ is given and the shift is known, $AI = (r+s) \tan \frac{1}{2} I = A'I$ in which r=radius of B B B″ and s=A B.

The object of the following problems is to connect a tangent line C A and a shifted curve B B B′ by means of a circular arc or a number of arcs of equal length, such that the difference of degree of the adjacent arcs shall be constant and shall not exceed 2,—the tangent line being considered a 0° curve,—and also to deduce the relation between the length of an arc of adjustment and the shift A B.

Problem I.—To find the length 'a' of a single arc of adjustment of radius $2r$, which shall connect a tangent line A C and a circular curve B B B′ of radius r, on which a cant c is due; the shift being A B$=s$.

The value of cant on the arc of adjustment is $\frac{1}{2}c$; then in passing from the tangent to the curve there will be two changes of cant each being $\frac{1}{2}c$.

Consider for the time the length a as known, and let $BB' = \frac{1}{2}a$ (Fig. 2).

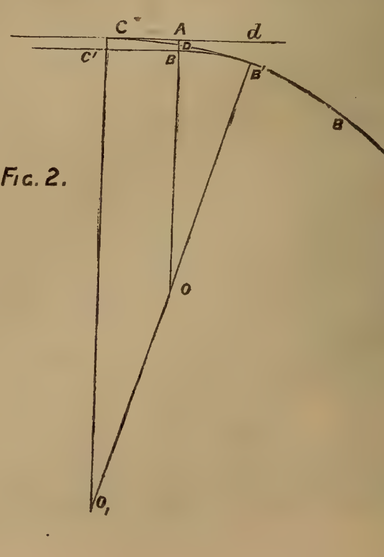


Fig. 2.

Draw $B'o$ and produce it until $B'o_1 = 2B'o = 2r$, with o_1 as centre and $o_1 B'$ as radius, describe an arc $B'C = a$, tangent to $B B' B$ at B', $C B'$ will then be tangent to $C A$ at C. For the angle at o_1 is equal to the angle at o, and consequently the tangent to $C B'$ at C coincides with or is parallel to $C A$, but by hypothesis the length $'a'$ is sufficient to connect the tangent line and curve, therefore $C B'$ is tangent to $C A$.

To find $'a'$:

Bisect the curve $C B'$, its middle point D will be on the line $A B$. The tangent deflection for a chord $'a'$ of a circle of radius r, represented by $t.\,d.\ (r.\,a)$, is $\dfrac{a^2}{2r} = T$; then

$$A D = t.\,d.\ (2r.\ \tfrac{1}{2}a) = \tfrac{1}{8}\frac{a^2}{2r} = \tfrac{1}{8}T$$

$$B D = t.\,d.\ (r.\ \tfrac{1}{2}a) - t.\,d.\ (2r.\ \tfrac{1}{2}a) = \tfrac{1}{8}T$$

$$\therefore\ s = A B = \tfrac{1}{4}T = \frac{a^2}{8r}$$

$$\text{Whence}\quad a = \sqrt{8\,r.\,s.}$$

When a is given

$$s = \tfrac{1}{2}\,t.\,d.\ (r.\,a) = t.\,d.\ (r.\ \tfrac{1}{2}a).$$

The following statements made in this, and similar statements made in subsequent problems, are not mathematically accurate ; that D the middle point of $C B'$ is on the line $A B$; that $B D = t.\,d.\ (r.\ \tfrac{1}{2}a) - t.\,d.\ (2r.\ \tfrac{1}{2}a)$; that chord $C D$ = arc $C D = \tfrac{1}{2}a$; the errors, arising from regarding such statements as true, are, however, too small to be regarded in railroad curves.

To lay out the curve of *Prob. I.*, a and s being known. For D the middle point of $C B'$, bisect $A B$; for C, measure back on the tangent line, from A a distance $A C = \sqrt{\tfrac{1}{4}a^2 - \tfrac{1}{4}s^2} = \tfrac{1}{2}a$; for B' measure, forward from A along the tangent line, a distance $A d = \sqrt{\tfrac{1}{4}a^2 - s^2}$, and at d lay out an offset whose length is $s + t.\,d.\ (r.\ \tfrac{1}{2}a) = 2s$. If the curve $B B' B$ be laid out from the auxiliary tangent $C'B$, the position of B' may be found by the sub-deflection angle for sub-chord $\tfrac{1}{2}a$; its value is

$$d' = \frac{a}{400}\,D$$

in which D is the degree of the curve.

Problem II.—To find the length $2a$ of a curve of adjustment, composed of two circular arcs of equal length of radii $3r$ and $\tfrac{3}{2}r$, which shall connect a tangent line $A c$ and a circular curve $B B' B$ of radius r, on which a cant c is due ; the shift being $A B = s$ (Fig 3).

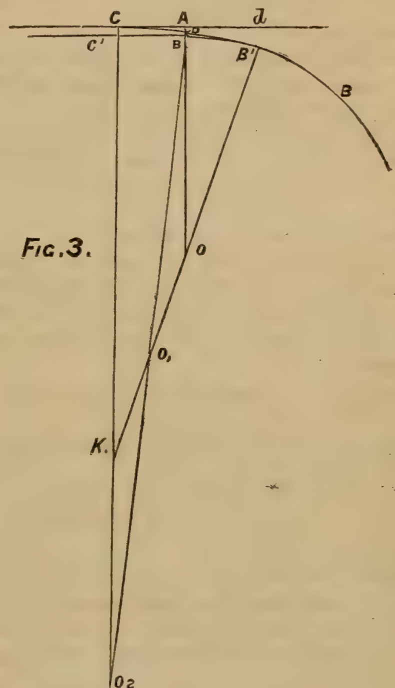


Fig. 3.

The values of cant are $\tfrac{1}{3}c\,c$, $\tfrac{2}{3}c$, so that in passing from the tangent to the curve there will be three changes of cant each of $\tfrac{1}{3}c$.

Consider $2a$ as known, and let $B B' = a$, draw the radius $B'0$ and produce it until $B'0_1 = \tfrac{3}{2}B'o = \tfrac{3}{2}r$; with o_1 as centre and $B'o_1$ as radius describe an arc $B'D = a$; draw $D o_1$ and produce it until $D o_2 = 3r$; with o_2 as centre and $D o_2$ as radius describe an arc $D c = a$; then will $C D B'$ be tangent to $C A$ at C. For draw the radius $C o_2$ and produce $B'o$ until it intersects it in R, then $\angle CRB' = \angle o_2 + \angle o_1 = \angle B o B'$, consequently $B o$ and $c o_2$ are parallel, and the tangent to $C D B'$ at C coincides with $A C$, since the length $2a$ is sufficient to connect the tangent line and curve.

To find $'a'$:

Bisect $C B'$ in D; it will be on the line $A B$.

$$A D = t.\,d.\ (3r.\,a) = \tfrac{1}{3}T.$$

$$\mathrm{B\,D}=t.\,d.\,(r.\,a)-t.\,d.\,(\tfrac{3}{2}\,r.\,a)=\mathrm{T}-\tfrac{2}{3}\,\mathrm{T}$$
$$=\tfrac{1}{3}\,\mathrm{T}.$$

$$\therefore \quad s=\mathrm{A\,B}=\tfrac{2}{3}\,\mathrm{T}=\tfrac{1}{3}\,\frac{a^2}{r}$$

Whence $a=\sqrt{3\,r\,s}$ $\;2\,a=\sqrt{12\,r\,s}$

When a is given

$$s=\tfrac{2}{3}\,t.\,d.\,(r.\,a).$$

To lay out the curve of *Prob. II.*; for D, bisect A B; for c measure back on the tangent line $\mathrm{A}\,c=\sqrt{a^2-\frac{1}{4}\,s^2}=a$; for B′, measure forward on the tangent line $\mathrm{A}\,d=\sqrt{a^2-\frac{9}{4}\,s^2}=\sqrt{a^2-\mathrm{T}^2}$, and at d measure an offset$=\frac{5}{3}\,t.d.(r.a)=\frac{5}{2}\,s$; or for B′ measure along c'B produced, a distance$=\mathrm{A}\,d$ and lay out an offet$=\frac{3}{2}\,s$. When the curve B B′B is laid out from the auxiliary tangent c'B, B′ may be located by a sub-deflection angle as in *Prob. I.* its value is

$$d'=\frac{a}{200}\,\mathrm{D}.$$

Problem III.—To find the length $3\,a$ of a curve of adjustment, composed of three circular arcs of equal length, of radii $4\,r$, $2\,r$, $\frac{4}{3}\,r$, which shall connect a tangent line A C and a circular curve B B′B of radius r, on which a cant c is due, A B=shift$=s$ (Fig. 4). The values of cant are $\frac{1}{4}\,c$, $\frac{1}{2}\,c$, $\frac{3}{4}\,c$, c.

As before, consider 'a' as known; let $\mathrm{B}\,b=\frac{1}{2}\,a$ (Fig. 4), and $\mathrm{B\,B'}=\frac{3}{2}\,a$, then $\angle \mathrm{B}\,o\,\mathrm{B'}=\frac{3}{2}\,\mathrm{B}\,o\,\mathrm{B'}$. Draw B′ o and produce it until $\mathrm{B'}\,o_1=\frac{4}{3}\,\mathrm{B'}o=\frac{4}{3}\,r$, with o_1 as centre and o_1 B′ as radius, describe an arc $\mathrm{B'\,D'}=a$; draw D′ o_1 and produce it until $\mathrm{D'}\,o_2=2\,r$, with o_2 as centre and D′ o_2 as radius describe an arc $\mathrm{D'\,D''}=a$; draw D″ o_2 and produce it until $\mathrm{D''}o_3=4\,r$, with o_3 as centre and D″ o_3 as radius describe an arc $\mathrm{D''}\,c=a$; then will B′ D′ D″ c be tangent to c A at c.

For draw $c\,o_3$ and produce B′o until it intersects $c\,o_3$ in K; $\angle \mathrm{C\,K\,B'}=\angle o_3+\angle o_2+\angle o_1=\frac{3}{2}\,b\,o\,\mathrm{B'}=\mathrm{B}\,o\,\mathrm{B'}$, consequently $c\,0_3$ and B 0 are parallel and c B′ (as in *Problems I.* and *II.*) tangent to c A at c.

To find 'a':

Produce the arc C D″ (Fig. 4 A) until $\mathrm{C\,D_1}=\frac{3}{2}\,a$ and the arc B′ D′ until $\mathrm{B'\,D_2}=\frac{3}{2}\,a$, and bisect CD″D′B′ in D. $\mathrm{D_1}$, $\mathrm{D_1D_2}$ may be considered as points in the straight line A B; then $\mathrm{A\,B}=\mathrm{A\,D_1}+\mathrm{D_1\,D}+\mathrm{D\,D_2}+\mathrm{D_2\,B}$. Let $\mathrm{T}=t.\,d.\,(r.\,a)$.

$$\mathrm{A\,D_1}=t.\,d.\,(4\,r.\,\frac{3}{2}\,a)=\frac{9}{16}\,\mathrm{T}$$

$$\mathrm{D_1\,D}=t.\,d.\,(2\,r\,\tfrac{1}{2}\,a)-t.\,d.\,(4\,r.\,\tfrac{1}{2}\,a)=\tfrac{1}{8}\,\mathrm{T}$$
$$-\frac{1}{16}\,\mathrm{T}=\frac{1}{16}\,\mathrm{T}.$$

$$\therefore \quad \mathrm{A\,D}=\tfrac{5}{8}\,\mathrm{T}.$$

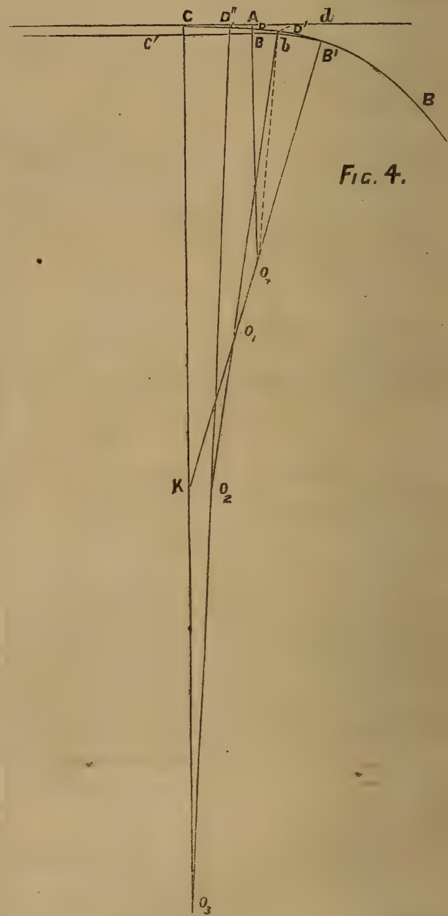


FIG. 4.

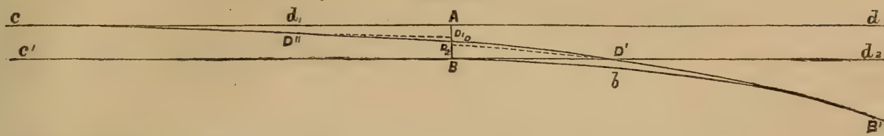
$$\mathrm{B\,D_2}=t.\,d.\,(r.\,\frac{3}{2}\,a)-t.\,d.\,\left(\frac{4}{3}\,r.\,\frac{3}{2}\,a\right)=\frac{9}{4}\,\mathrm{T}$$
$$-\frac{27}{16}=\mathrm{T}\,\frac{9}{16}\,\mathrm{T}.$$

$$\mathrm{D_2\,D}=t.\,d.\,\left(\frac{4}{3}\,r\,\tfrac{1}{2}\,a\right)-t.\,d.\,(2\,r.\,\tfrac{1}{2}\,a)$$
$$=\frac{3}{16}\,\mathrm{T}-\tfrac{1}{8}\,\mathrm{T}=\frac{1}{16}\,\mathrm{T}.$$

$$\therefore \quad \mathrm{B\,D}=\tfrac{5}{8}\,\mathrm{T}=\mathrm{D\,A}.$$

$$s=\mathrm{A\,B}=\tfrac{5}{4}\,\mathrm{T}=\tfrac{5}{8}\,\frac{a^2}{r}, \quad \therefore \quad a=\sqrt{1.6\times r.\,s.}$$

FIG. 4. A.



When 'a' is given

$$s=\tfrac{5}{4}\ t.\ d.\ (r.\ a).$$

Points in the curve C D″ D D′ B′ are found as follows :

$$A\,C=\tfrac{3}{2}\,a \text{ nearly.}$$

$$A d_1=\tfrac{1}{2}\,a \text{ nearly, } d_1\,D''=t.\ d.(4\,r.\ a)=\tfrac{1}{4}\,T =\tfrac{1}{5}\ s.$$

$$A\,D=D\,B=\tfrac{1}{2}\,s.$$

$$B\,D'=\sqrt{\tfrac{1}{4}\,a^2-\tfrac{1}{25}\ s^2}=\tfrac{1}{2}\,a \text{ nearly.}$$

$$D'\,b=t.\ d.\ (r.\ a)-t.\ d.\ (\tfrac{4}{3}\,r.\ a)=\tfrac{1}{4}\,T=t.\ d.\ (r.\ \tfrac{1}{2}\,a).$$

$\therefore$ D′ is on the auxiliary tangent C′B d_2.

$$B'd_2=\sqrt{\tfrac{9}{4}\,a^2-t.d.\ (r.\ \tfrac{3}{2}\,a)^2}=\sqrt{(\tfrac{3}{2}a)^2-(\tfrac{9}{5}s)^2}$$

$$d^2\,B'=t.\ d.\ (r.\ \tfrac{8}{2}\,a)=\tfrac{9}{4}\,T=\tfrac{9}{5}\,s.$$

The point B′ may also be found by a sub-deflection angle, whose value is

$$\frac{3\ a}{400}\,D=\angle\, d_2\,B\,B'.$$

Problem IV.—To find the length, $4\,a$, of a curve of adjustment, composed of four circular arcs of equal length, of radii $5\,r$, $\frac{5}{3}\,r$, $\frac{5}{4}\,r$, which shall connect a tangent line A C and a circular curve B b B′B of radius r, on which a cant c is due. A B=shift=s. The values of cant are $\frac{1}{5}\,c$, $\frac{2}{5}\,c$, $\frac{3}{5}\,c$, $\frac{4}{5}\,c$, c. (Fig. 4). Consider a as known ; let B $b=a$ and B B′$=2\,a$, and proceed as in *Prob. III.* In this case, however, $B'o_1=\frac{5}{4}\,r$, D $o_2=\frac{5}{3}\,r$, $D''o_3=\frac{5}{2}\,r$, and $D''o_4=5\,r$.

To find a :

Produce the arc C D″ until C $D_1=2\,a$, and the arc B′ $D_2=2\,a$, and bisect C D″ D D′ B′ in D ; D_1, D, D_2 may be considered as points in the straight line A B.

Let $T=t.\ d.\ (r.\ a)$.

$A\,D_1=t.\ d.\ (5\,r.\ 2\,a)=\frac{4}{5}\,T.$

$D_1\,D=t.\ d.\ (5\,r.\ a)-t.\ d.\ (\frac{5}{2}\,r.\ a)=\frac{1}{5}\ T.$

$\therefore$ A D=T.

$B\,D_2=t.\ d.\ (r.\ 2\,a)-t.\ d.\ (\frac{5}{4}\,r.\ 2\,a)=\frac{4}{5}\,T.$

$D_2\,D=t.\ d.\ (\frac{5}{4}\,r.\ a)-t.\ d.\ (\frac{5}{3}\,r.\ a)=\frac{1}{5}\ T.$

$\therefore$ B D=T=A D.

$$s=A\,B=2\,T=2\,\frac{a^2}{2\,r}\quad \therefore\quad a=\sqrt{s.\ r.}$$

When a is given

$$s=2\,T=\text{chord deflection } (r.\ a).$$

The points C, D″, D, D′, B′ are located as follows :

D is the middle point of A B.

Point.	From A B.	From C A.
C	$2\,a$ nearly.	0
D″	a nearly.	$\frac{1}{5}\,T=\frac{1}{10}\ s.$
		From C′B d_2.
D′	$\sqrt{a^2-\frac{1}{4}\,s^2}$	$\frac{4}{5}\,T=\frac{2}{5}\ s.$
B′	$2\sqrt{a^2-s^2}$	$4\,T=2\,s.$

The value of the sub-deflection angle b_2 B B′ is

$$\frac{a}{100}\,D$$

The curves of *Probs. I.—IV.* are sufficient to flatten the extremities of any circular curve whose degree does not exceed 8. Any number of arcs of equal length may, however, be used. Let $2\,n$= number of arcs; and $a=\dfrac{\text{length of curve}}{2\,n}$; then

$$s=\frac{n^2+n}{3}\ t.\ d.\ (r.\ a).$$

The distance from C A, of any point in the curve, is

$$y=\frac{t.\ d.\ (r.\ a)}{6\ (2\ n+1)}\ (2\ m^3+3\ m^2+m)$$

in which m is the number of arcs from C to the point. For B′, $m=2\,n$, and

$$y=\frac{4\ n^2+n}{3}\ t.\ d.\ (r.\ a)=s+n^2\ T.$$

The distance, along A C, of any point from C, is

$$x=\sqrt{m^2a^2-y^2}=m\,a \text{ nearly.}$$

Unless the curve of adjustment be of great length, the points C, D and B′ will be sufficient to fix the curve; in all cases, D is the middle point of the shift ; C is on the tangent line at a distance from A$=n\,a$ nearly ; and B′ is on the curve

B B′B, and may be found by a sub-chord $n\,a$ and the sub-deflection angle d_2 B B′ $=\frac{n\ a}{200}$ D.

The numerical work will be considerably shortened if the length of the curve of adjustment be assumed and s calculated. If the gradient of the outer rail be taken as about 1 : 300, the length of curve of adjustment$=25\times$D, when V$=$40. The calculation will be further simplified if the length of curve $\div\ 2\,n$ be a whole number.

The shift. $s=\frac{n^2+n}{3}$T$=$N T.

$$T=t.\ d.\ (r.\ a)=\frac{a^2}{200}\sin 1°\times D$$
$$=0.00008722\ a^2\times D.$$

$$T=T'.\,D.\quad \therefore\quad s=N.\,T'.\,D.$$

Tables I. and II. give values of T′ and N for different values of a and $2\,n$:

TABLE I.

a	T′	a	T′	a	T′	a	T′
15	.0196	37	.1194	59	.3036	81	.5723
16	.0223	38	.1259	60	.3140	82	.5865
17	.0252	39	.1327	61	.3246	83	.6009
18	.0283	40	.1396	62	.3353	84	.6154
19	.0315	41	.1466	63	.3462	85	.6301
20	.0349	42	.1539	64	.3573	86	.6451
21	.0385	43	.1613	65	.3685	87	.6602
22	.0422	44	.1689	66	.3799	88	.6754
23	.0461	45	.1766	67	.3915	89	.6908
24	.0502	46	.1845	68	.4033	90	.7065
25	.0545	47	.1927	69	.4153	91	.7223
26	.0590	48	.2010	70	.4274	92	.7382
27	.0637	49	.2094	71	4397	93	.7544
28	.0684	50	.2180	72	.4522	94	.7707
29	.0734	51	.2268	73	.4648	95	.7872
30	.0785	52	.2358	74	.4776	96	.8038
31	.0838	53	.2450	75	.4906	97	.8206
32	.0893	54	.2543	76	.5038	98	.8376
33	.09498	55	.2638	77	.5171	99	.8548
34	.1008	56	.2735	78	.5306	100	.8722
35	.1068	57	.2834	79	.5443		
36	.1130	58	.2934	80	.5582		

TABLE II.

$2\,n$	N	$2\,n$	N	$2\,n$	N	$2\,n$	N	$2\,n$	$N=\frac{n^2+n}{3}$
1	$\frac{1}{4}$	3	4	5	$\frac{35}{12}$	7	$5\frac{1}{4}$	9	$8\frac{1}{4}$
2	$\frac{2}{3}$	4	2	6	4	8	$6\frac{2}{3}$	10	10

Example.—Given B B′B, a $6\frac{1}{2}°$ curve, and $2\,n$=4=number of arcs in curve of adjustment; to find the shift, s, when the gradient of the outer rail is about 1 : 300 and V=40.

Length of curve$=25\times$D$=162'$, make a=40.

Table I.—a=40 T′=0.1395.

Table II.—$2\,n$=4 N=2.

$\therefore\ s=2\times 0.1395\times 6.5=1.'81=1'\ 9.''7.$

The curve B B ′B. When the tangent points A, A′, (Fig. 1.) are fixed and the degree of the curve A A A′ is known, the shift may be calculated for this curve, since A A A′ and B B′ B B″ may be considered of the same degree. In staking

out the curve A A A′, a point, at each end of the curve, corresponding to B′ may be found, very approximately, by using the sub-chord $n\ a$ and the sub-deflection angle whose value is $\frac{n\ a}{200}$ D ; B B′B is then located by shifting every stake of A A A′ through a distance= A B=shift.

When the angle of intersection of the two tangent lines is given and the degree of the connecting curve is known, it will often be convenient to take this degree as the degree of BB′B and to locate the curve between the auxiliary tangents B_1 B, B″B_1. In this case the distance from I the point of intersection of the tangent lines to A or A′ is

$$A\ I = A\ ' I = (r+s) \tan \tfrac{1}{2} \angle I.$$

In practice, curves of more than 6° are seldom met with ; therefore in the great majority of cases, one or two arcs in the curve of adjustment will be sufficient to flatten the extremities of the curve ; it will be convenient in these cases, to make the length of an arc of adjustment=100′ in which case the tangent deflection will be found directly from the tables of Henck's Field Book and the shift will become

$\frac{1}{4}$ T or $\frac{3}{4}$ T, according as one or two arcs are used.

In the absence of tables

Shift (for one arc)=$\frac{1}{4} \times .8722 \times$D = 0.218 D.

Shift (for two arcs)=$\frac{2}{3}$.8722 $\times$ D= 0.581 D.

The value of the deflection angle d_2 B B′ (Fig. 4 A,) will then be $\frac{1}{4}$ D for curves or one arc, $\frac{1}{2}$ D for curves of two arcs.

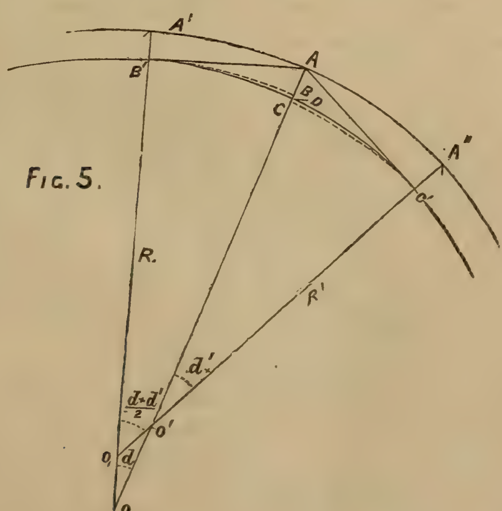
COMPOUND CURVES.

When, in passing from one branch of a compound curve to the other, the change of cant is small, that is to say, when D∼D′ $\leqq$ 2, the shifts of the two branches may be made equal, and the change of cant between the branches "humored in." The shift should be calculated for the sharp branch and from this the length of the curve of adjustment for the flat branch.

When D∼D′>2, one arc of adjustment of degree $\frac{D+D'}{2}$ giving two equal changes of cant, will, in the majority of cases, be sufficient to correct the branches of the curve.

Let A′ A of radius R and degree D and A A″ of radius R′ and degree D′ be the two branches of the compound curve A′A A″, Fig. 5 ; and let the length of the arc of adjustment be $'a'$ and its radius r ; then $r = \frac{2\,R\,R'}{R+R'}$ for r : R=D ;

Fig. 5.



$\frac{D+D'}{2}$ (Fig. 5.) and $R+R' : R' = D+D' : D$ from which $r = \frac{2RR'}{R+R'}$

Let B B′ and C C′ be the shifted positions of the branches of the compound curves, since the shifts are comparatively small, we may say, radius of B B′=R and radius of C C′=R′. Consider $'a'$ as known and let the shift A A″=A C=$t.\ d.$ $(R'.\frac{1}{2}a)$ and the shift of A′A=A B=$t.\ d.\ (R+\frac{1}{2}a)$, then will B′A∼C′A. Draw the radii B′O, A O, C′O′ and let d and d' be the central angle; produce C′ O′ until it cuts B′ O in O_1 then $B'\ O_1\ C' = \frac{d+d'}{2}$ and since A B′ = A C′, O_1 will be the centre of a circle passing through B′ and C′ and tangent at these points to B′ B and C′ C. The middle point D of this arc is on the line A C, $i.\ e.$ B′ D=B C′=$\frac{1}{2}a$.

To find $'a'$ and the position of D:

$$A\,D = t.\ d.\left(\frac{2RR'}{R+R'}\cdot\frac{1}{2}a\right)$$

$$B\,D = t.\ d.\left(\frac{2RR'}{R+R'}\cdot\frac{1}{2}a\right) - t.\ d.(R\,\tfrac{1}{2}\,a)$$

$$= \frac{a^2}{8}\ \frac{R'-R}{2RR'}$$

$$D\,C = t.\ d.\ (R'\tfrac{1}{2}\,a) - t.\ d.\left(\frac{2RR'}{R+R'},\tfrac{1}{2}a\right)$$

$$= \frac{a^2}{8}\cdot\frac{R'-R}{2RR} = B\,D.$$

$$\therefore\quad B\,C = 2\,B\,D = \frac{a^2}{8}\cdot\frac{R'-R}{RR'}.$$

And D is the middle point of B C.

Find the length of the curve of adjustment which shall connect the sharp branch of the curve and its tangent line, and from this find the value of the shift A C; A C=$t.\ d.\ (R'.\frac{1}{2}a) = T'_1 D'$, from which, by Table I., may be found the value of C C′=$\frac{1}{2}a$; find also A B=$t.\ d.\ (R.\frac{1}{2}a) = T'_1\ D$, which is the value of the shift of the flat branch, and from which the length of the curve of adjustment which shall connect it with its tangent line must be calculated.

Example.—A A″, the sharp branch is a 5° 30′ curve, and has a curve of adjustment of 3 arcs, of 40′ each; A′ A is a 3° curve, which is to have a curve of adjustment of 2 arcs.

Shift=A C=N T'_{40}.D′=$\frac{4}{4}$ × .1396×5½ =.1745×5½=.959′.

$=t.\ d.\ (R'.\frac{1}{2}a) = T'_1\ D' \quad \therefore\quad T'_1 = \frac{.959}{5\frac{1}{2}}$ =.1745.

Entering Table I. with this value we have $\frac{1}{2}a$=45′ nearly.

∴ B′ D C′=90′ approx.

Shift for flat arc=A B=T'_1 D=.1745×3 =.5235′=N T′D=$\frac{2}{3}$. T′ .3 = 2 T′, ∴ T′=.2617.

Entering Table I., we find that the length of an arc of adjustment to be 55′ nearly.

A D=$\frac{1}{2}$ (A B+A C) = .741′.

REVERSED CURVES.

Let B A C be a reversed curve, and A the point of reversing; determine the length $2\,n\,a$ of the curve of adjustment, and let A B′ (Fig. 6) = $n\,a$. Find the value of

$$\frac{AB'.\,AO'}{AO} = \frac{n\,a.\,r'}{r}$$

and let this be the value of $n'\,a'$=A C′, ∠:e. $\frac{1}{2}$ length of the curve of adjustment for the flat branch of the curve; draw the radii oB′, o' C′ which will be parallel, and consequently a line drawn through A perpendicular to o' C′ will be perpendicular to oB′; moreover dB′=$t.d.\ (r.\,n\,a) = n^2$ T, and C′ $d_1 = t.\ d.\ (r'.\,n'\,a') = n'^2\,T_1$. With o as centre and $o\,d$ as radius describe the arc $B_1\,d$, and with o' as centre and $o'\,d_1$ as radius describe the arc $d_1\,c_1$ and join $d\,d_1$, which will be tangents to both arcs.

Calculate the shift for the arc $B_1\ d$, the length of the curve of adjustment being $2\ n\ a$; also calculate the shift for the arc $d_1\ c_1$, the length of the curve of adjustment being $2\ n'\ a'$. Since the distance B′d is small compared with r we may say

$$\text{Shift for } B_1\ d = d\ b' = \frac{n^2+n}{3}\ t.\ d.\ (r.a.)$$

So also

$$\text{Shift for } c_1\ d_1 = d_1\ c' = \frac{n'^2+n'}{3}\ t.d.(r'.a')$$

The curve of adjustment for $B_1\ d$ bi-

Fig. 6.

sects $d\,b'$ and the curve of adjustment for $c_1\,d_1$ bisects $d_1\,c'$.

These curves are tangent to $d\,A\,d_1$ at A.

The total shift,

$$\text{For } B\,A = B'\,b' = A\,a = n^2\,T + \frac{n^2+n}{3}\,T = \frac{4n^2+n}{3}\,T.$$

$$\text{For } c\,A = C'\,c' = A\,a_1 = n'^2\,T_1 + \frac{n'^2+n'}{3}\,T_1 = \frac{4n'^2+n'}{3}\,T_1.$$

These are, of course, the values of the shifts at the ends of the curve from which the lengths of the curves of adjustment which connect the curve and its tangent lines must be calculated.

Example.—B A the sharp branch of a reversed curve is of 6°, at its junction with the other branch it is to have a curve of adjustment of 6 arcs each of 20′, and a curve of 4 arcs is to connect it and its tangent line. The flat branch A C is of 4° 30′, at its junction with the first branch it is to have a curve of adjustment of 4 arcs and a curve of 2 arcs is to connect it and its tangent line.

$$n\,a = 3\times 20 = 60,\ n\,a' = \frac{6}{4.5}\cdot 60 = 80\ \therefore\ a' = \frac{80}{2} = 40'.$$

$$\text{Shift for } B\,A = \frac{4\,n^2+n}{3}\,T = \frac{4\,n^2+n}{3}\,T'\,D = 13\,T'\,D = 78\,T = 78\times .0349 = 2.728.$$

$$\text{Shift for } C\,A = \frac{4n'^2+n'}{3}\,T = 6\times 4\tfrac{1}{2}\times T' = 27\times .1396 = 3.'77.$$

At the ends of the curve we have

For $B\,A_1$ shift$=2.72=N\,T\,D$, $N\,T'=.4537$ here $N=\frac{n^2+n}{3}=2\ \therefore\ T'=.2268$ and $a=51$=length of an arc of the curve of adjustment which connects B A and its tangent line:

For $C\,A_1$ shift$=3.77=N\,T'\,D$. Here $N=\frac{2}{3}$ 1. $T'=1.2564$ and $a=120'$ approximately.

TIDAL SCOUR IN RIVERS.*

By Mr. C. Richardson.

From "The Engineer."

The object of this paper is to draw the attention of this section to a few facts bearing upon the question, "Do the tidal waters in ebbing and flowing along a river channel tend to keep that channel open?" The channel of the Avon between Kingroad and Bristol will naturally occur to every one present here, and on that channel our remarks shall begin ; but it will be necessary to bear in mind, throughout this discussion, that the form of the channel through the alluvium alone is considered. Wherever

* A paper read before the British Association.

rock or other hard substance appear, the conditions of the question are entirely changed, and the facts mentioned may no longer apply.

Now, if the river channel be carefully inspected at low water of a spring tide, flakes of mud may be observed to slip down into the low-water stream here and there as the tide recedes ; the hollows these mud-slips leave are characteristic, and are plainly observable all along the river at low water. These patches of mud slip into the low water channel as they lose the support of the tidal water, and are then carried out into the Severn by the stream. The low water section across the Avon, as above described, will be found to apply to the whole length of the channel from Pill to Bristol, with the exception that towards Pill the low water channel is something wider than it is higher up the river, but the mud slopes will be found at about the same angle.

This fact clearly indicates two things: first, that the mud has been deposited by the tidal waters—for how else did the mud get there? and, secondly, that the means of carrying it off resides in the low water current, for otherwise the accumulation of these mud-slips would gradually raise the level of the low water channel, a fact which is against all experience.

In what has been said above, the action of wind has been left out of the question, and these observations are supposed to have been made at those times when there was little or no wind to affect them. It will be found, however, that the action of the wind, where it can be well observed, tends to prove the same fact, namely, that the tidal waters do deposit the mud in quiet times. For example, at the ferry from Pill to Lamplighter's, the Lamplighter's shore is entirely alluvial, and it will be found that during a quiet season the mud on that shore will rise to a level of 5 ft. or 6 ft., on both sides, above the level of the ferry path. If, after this, a continuance of strong westerly winds sets in, the ripple on the water will gradually wash away the accumulated mud again until it becomes almost level with the ferry path. This fact proves that the tidal waters do, of themselves, have a tendency to deposit mud, but that the ripple caused by the wind washes it away again in exposed situations near the mouth of the river.

Looking now at other streams under similar circumstances, one of the largest on the same shore is the Main Reen, which runs into the Severn at Chessel Pill, at the new passage. The history of this stream is instructive. First of all, it was dammed at the old footbridge at Redwick, a mile inshore, representing very fairly the damming of the Avon at at Netham, if due allowance is made for the comparative volume of the two streams. The commissioners then, for the benefit of the level, built a new dam near the mouth of the stream. This would be like damming the Avon at Hungroad. And what has been the result? Inside the dam the mud slopes have become grass-grown ; but outside the dam there is no perceptible difference in the external channel. It has no tendency to mud up or alter in any way ; the channel is just as wide and as deep, and the mud slopes remain the same, mud-slips taking place into the stream at low water, and being washed away by the fresh water in the same way as has been described.

Looking next at the smaller streams, what do we see? That the tidal channels or estuaries are solely and entirely governed in their dimensions by the quantity of fresh water that comes down. The writer intended to have gauged the flow of water and to have measured the tidal channels of a number of these, but he had not time to do so. He has not the least doubt that if this had been done it would have been found that the tidal channel, in its dimensions, always bears a direct proportion to the quantity of fresh water that comes down.

This fact is quite apparent to any one who has been in the habit of observing these things ; he will look carefully at the different streams in the neighborhood, he will see little streams with little estuaries, medium streams with middle-sized estuaries, and big streams with large estuaries, the channel formed being always in proportion to the amount of fresh water. This cannot be accounted for on any other supposition than that the volume of the fresh water determines the size of the estuary, and that the tidal waters have nothing at all to do with it.

THE EFFECT OF DEAD SPACE IN WOOLF ENGINES.

By O. HOLLAUER.

Translated from Bulletin de la Soc. Indust. de Mullhouse.

I.

This important question of dead space in the case of single cylinder engines has been treated by Zeuner in *La Theorie Mécanique de la Chaleur*, page 493 of Arnthat and Cazins translation.

In this remarkable work the author first considers the case of a one cylinder engine without dead spaces consuming a weight M of mixed steam and water, leaving the boiler to fill the initial volume $V_1=0.^m04949$ offered by the cylinder during admission; the total volume being $V=0.^m29698$. He then calculates work due to full pressure $V_1 p_2$ and expansion; using the exponent $M=1,035+0,100\,x_2$ in the formula

$$L_v=\frac{p_2 V_1}{m-1}\left(1-\left(\frac{V_1}{V}\right)^{m-1}\right)$$

Then he estimates all losses due to imperfection of cycle, incomplete expansion, loss of pressure between boiler and cylinder, inequality between external pressure and counter pressure; loss due to constant resistance and the variable resistance of friction; and he deduces 7.72 k as the hourly consumption per H. P., corresponding to an admission of one-sixth.

Then, considering an engine with dead spaces, he says:

"Dead space exerts an important influence upon the working. Its inconveniences are mainly due to the fact that steam is admitted into a space holding steam of feeble tension, so that the engine uses more than one without such dead spaces. It is true that the work which corresponds to this additional mass of steam is not entirely lost since it shares in the expansion. In spite of this that work is too great to be neglected."

The weight of the steam admitted into the dead space and the volume generated $(V'+V_1)$ is $M_o>M$, that was consumed in the preceding case, and the author proves that there is evaporation of water during the introduction of the steam into the cylinder, in consequence of the dead spaces.

He afterwards considers: (1) the loss due to imperfection of cycle; (2) that due to dead space; (3) to difference of tension in boiler and cylinder; (4) to inequality of counter pressure and exterior pressure; (5) to the constant resistance of friction; (6) to the variable resistance of friction. He finally fixes as the rate of hourly consumption per effective horse power, 8.478 k'.

The suppression of the dead space $V'=0,01485$ cubic metres, when the volume generated was $V_1=0,04949$ C. M. reduces the consumption

$$\frac{8,478\text{ k}-7,720\text{ k},}{8.478}=8\ \%,\ 94.$$

To prevent this, Zeuner attempts to condense the escaped steam until the tension in dead spaces is equal to that in the boiler. Remarking that this causes a new loss of work which may balance the gain of the process, he says:

"When, in an ordinary engine, the condensation of steam behind the piston is kept up until that which is in the dead spaces reaches the same point as that in the boiler, the engine then acts as one without dead spaces, so that the escape of steam goes on during the entire stroke of the piston."

He finally proposes that the steam may be superheated when the limit of condensation is reached. "While the piston retrogrades a certain space a corresponding volume of steam leaves the cylinder; the steam remaining behind probably contains little water. Now, as the mixture is compressed there will probably result a partial or total vaporization of the water; and it may happen that at the limit of the compression the steam in the dead space will be superheated. Unfortunately, we do not yet know how the mixture of this superheated vapor and the saturated steam from the boiler is effected; but this question is here of little importance; our main object being to show that compression is accompanied by a vaporization of the

water mixed with steam, so as to cause superheating the steam left behind."

It is to be regretted that Zeuner has not taken into account the disturbing effect of the walls of cylinders ; an effect pointed out by Hirn in his edition of 1865 ; which experiments have established beyond a doubt, even in the case of superheated steam.

The walls which absorb heat during admission, condense often a considerable portion of the steam which flows from the boilers, and restore a part during the period of expansion. This occurs by means of the coating of water which covers them. This evaporates and increases the amount of steam on the cylinders. The action is quite complicated, and modifies in a great degree all the series of phenomena of which work is the resultant. It seemed impossible to neglect its effects in the deterioration by experiment of the influence of compression and loss by dead space upon consumption.

In previous publications in the *Bulletin*, we have given the loss due to dead space ; but the method followed in the evaluation was not attended by all the checks required in experimental researches ; the purely algebraical discussion depending upon a hypothesis not physically warranted.

After having determined upon the same curves the exponent of the law of expansion, formulas for work are determined, evaluated for dead spaces both for single cylinder and Woolf engines. The values so obtained are very close to those determined by the planimeter upon the diagram areas.

For the same engines, supposed without dead spaces, exactly the same volume of steam is admitted as in the former case ; and the work is estimated on the hypothesis that the exponent of expansion remains the same. The difference between the values obtained should give the amount of loss. But all this depends on the unproven hypothesis that the exponent of the law of expansion is the same when the same volume is introduced into a cylinder either with or without dead space. The examination of many diagrams from the same motors, with different admissions, has proven that the exponent varies with the volume introduced. Are we to conclude that it will not vary for engines with and without dead space, or that the exponent remains constant for the same volume admitted whatever the amount of dead space?

Take first the case of single cylinder engines, in which the dead space may be reduced to a small fraction of the volume generated, and let us seek for the manifold causes which influence the approximate law of expansion denoted by the exponent m or a. As in this kind of engines the discharge steam is not greatly compressed, all the walls of the dead space, as well as the cylinder, are cooled during the period of discharge into the condenser.

When the next charge of steam comes from the boiler, it encounters walls not sufficiently heated by the compression and condenses, giving up a considerable quantity of heat. This condensation may amount to 60 per cent. of the steam admitted when there is no jacket.

The heat is partially restored during expansion ; it allows a continual evaporation of the coat of water which covers the walls previously warmed. At last the envelop of steam diminishes condensation and increases evaporation in the cylinders. These processes, combined with the disappearance of heat due to expansion, are the two sole causes that affect the law of expansion, and fix the value of the exponent of that law.

Suppose the dead spaces removed, and that the same volume of steam is introduced into the cylinders. As the surfaces differ, the condensation during admission and the evaporation during expansion will be changed, as well as the work of expansion ; all being causes that modify the exponent of the law of expansion, and which show the falsity of the hypothesis upon which the formulas for work have been based. But as the dead space in single cylinder machines, especially such as those of Hirn & Corliss, is quite small relatively to the final volume, these formulas can be applied with sufficient approximation.

But this is not the case with the vertical Woolf engines, in which the dead space between the two cylinders is enormous ; as, for example, in that of Dollfus-Mieg ; in which it is, for the small cylinder one-thirtieth, for the large one-eighth of the total volume. In a pre-

vious paper we have indicated the distinction that must be made between the two simultaneous losses due to dead space and condensation between the cylinders. But this correction does not remove the error inherent in those formulas which are based upon the hypothesis that the exponent is the same.

We must analyze the transformations of the steam during its passage through the dead spaces and during compression ; an analysis which alone can give satisfactory results by givng us the key to the thermic phenomena that take place in the dead spaces.

We will give in full detail the results obtained by us in the solution of this problem.

The Woolf engine of 200 H. P., which was the subject of our investigations, has two cut-offs. The steam of the small cylinder escapes into the distributing chest of the larger. The compressed steam is contained under the small piston and between these two cut-offs, which have just the same motion.

The pressures were determined by Watt's indicator with sufficient exactness. The usual objections to this instrument, which are founded upon circumstances due to the use of a spring in regulating the movement, do not hold in the case of a Woolf engine admitting at full pressure during almost its whole stroke. The springs do not have to bear sudden changes of pressure as in the case of single cylinders with great expansion ; so that the inertia and friction of the different pieces may be neglected.

Again we traced upon the sheet containing the curves, according to Zeuner's method, the diagram of distribution which allows us to follow the movement of the slides and to control the positions for the critical points of work, as shown by Watt's indicator.

Consider the small piston at the beginning of its course. The steam enters from the boiler during the entire period of admission and becomes mingled with that in the dead spaces. When it has left the boiler to enter the cylinder a mixture of 0,6956 k containing 0,0278 k of water, which the weight of saturated steam

$$0{,}2362 \text{ cub. m.} \times 2{,}3780\,k = 0{,}5617\,k.$$

A part of this steam condenses upon the walls.

0,6956 + 0,0125 k remains in the dead space, less 0,5617 k, or $20\frac{67}{100}$ per cent. Subtracting 4 per cent. of water, there remains $16\frac{67}{100}$ per cent. of condensation.

The small slide during lap intercepts communication. Expansion lasts until the moment when the escape opens. The steam immediately enters the dead spaces between the small and large cylinder ; then, the advance to admission being slower than that to escape, it passes immediately into the large cylinder, when the port has opened. This discharge with expansion is interrupted at about fifteen-twentieths of the course by the exterior lap of the large slide closing the admission orifice ; and there is between the small piston and the port of the large cylinder a volume of compressed steam, viz. :

0,0806 cub. met. under the small piston and in the port of the small cylinder.

0,0890 cub. met. between the small slide and the port of the large.

Making a total of 0,1696 cub. met. at a pressure of 0,650 kil., giving a weight of saturated steam of 0,1696 cub. met. ×0,3913 k. = 0,0664 k. But we must know the quantity of water, whether in suspension or deposed upon the walls, in order to be able to determine the total internal heat U of the mixture. The curve from the large cylinder gives the weight of water as exactly as possible.

As soon as the large slide closes there is in the large cylinder 1,4176 c. m. of saturated steam at 0,620 k. pressure, weighing 0,4176 c. m. × 0,3744 k. = 0,5307 k. With this we are to compare 0,6956 directly gauged and furnished by the boiler at each piston stroke, increased by 0,0223 k., which remain in the large cylinder after the escape to the condenser. For the liquid in the steam

$$0{,}6956\text{k.} + 0{,}0223\text{ k.} - 0{,}5307\text{ k.} = 0{,}1872\text{k.}$$

or

$$\frac{0{,}1872}{0{,}66956 + 0{,}0223} = 26\,\% +$$

We may without appreciable error suppose that this proposition was the same in the small cylinder at the instant of interruption, the two cylinders having been in full communication up to

this moment. The mixed steam and water between the small piston and the port of the large slide at a tension of 0,065 k. is composed of 0,0664 k. of steam, and $0,064 \times \frac{0,1872}{0,5307} = 0,234$ k. of water.

Total, 0,0898 k.; of which the internal heat

$$U = 0,0664\ q + 0,0898\ q$$

$$= 0,0664\ \mathrm{k} \times 505,76\mathrm{c} + 0,0898\mathrm{k} \times 87,88\mathrm{c}.$$

$$= 33,58\ \mathrm{c.} + 7,89\ \mathrm{c.} = 41,47\ \mathrm{c.}$$

Is this heat augmented by the compression?

This can be easily determined by finding the composition of the mixture 0,0898 k.

At sixteen-twenty, seventeen-twenty, eighteen-twenty of the course, points at which we find the pressures

0,723; 0,850; 0,993 k.

and consequently:

Pressures.	t	q	q	β	Volumes	Steam.	Water.	%	U
0k,723	90°,31	90c,69	503c,57	0k,43252	0m3,4598	0k,0691	0k,0207	23%,05	42c,94
0k,840	94°,63	95c,06	500c,45	0k,50353	0m3,4448	0k,0729	0k,0469	48%,82	45c,09
0k,993	98°,89	99c,37	496c,78	0k,58271	0m3,1299	0k,0757	0k,0441	45%,70	46c,53

REPORT OF IRON AND STEEL INDUSTRIES—METALLURGICAL TECHNOLOGY.*

Journal of the Iron and Steel Institute.

Magnetism of Iron.—It has generally been accepted that iron at a red heat was incapable of being rendered magnetic, and this was sustained by Elias, in *Poggendorf Annals* for 1872; the reverse of this is now, however, maintained by M. Gaugain, in a communication to the Academy of Sciences, in Paris, February 1st, who states that if it is wished to saturate a bar of iron with magnetism, the best method of doing so is to magnetize it whilst its temperature is very elevated.

Magnetism of Steel.—Commandant Treve has communicated to the Academie des Sciences the results of experiments made by himself and M. Durassier, the head of the chemical department at the Creusot Works, on the connection which exists between the nature of steel and its magnetic force. Fifteen bars of steel were selected, which were divided into five sets, each of which received a different temper, after which M. Treve magnetized them to saturation, and then determined their magnetic force by the method of deviation. Those bars which contained 0.950 per cent. of carbon, and which were hardened in cold water, gave a maximum of deviation represented by the number 47; whilst a bar with the same amount of carbon, but hardened in boiling water, gave the number 44: and a third bar, also with the same amount of carbon, but hardened in oil of a temperature of 10° Centigrade (50° Fahrenheit) only gave 43, showing that the fluid used in hardening exerts an influence. The effect of the amount of carbon contained in the steel is also established, for whilst the maximum of deviation of the above-mentioned bars, which contained 0.950 per cent. of carbon, was found to be 47, other bars containing 0.250 per cent. of carbon only showed a deviation of 13. In laying down the curves of variation, the influence of the amount of the carbon and of the hard-

* Taken from the report to the Iron and Steel Institute by David Forbes, F. R. S.

ening media was sensible enough, but the effect of the latter was smaller in proportion as the former increased, and M. Treve has ascertained the fact that the magnetic curve of a steel bar coincides with its curve of elasticity, thus proving that carbon not only gives to steel its elasticity but also its magnetic capacity.

Magnetic Separation of Iron and Steel.—Some time ago we called attention to certain machines which were employed on the river St. Lawrence, in Canada, for concentrating by means of magnetism the ferruginous sands so abundant in those parts, and in which the iron existed in the state of the native magnetic oxyde of this metal; we now call attention to a somewhat similar arrangement called a magneto-mechanical separator, which has for object the separation of iron and steel filings from the copper, brass, and other filings, which accumulate in the workshops. The machine is the invention of Mr. Charles Vavin, and was described by M. Bouillet at the meeting on the 1st May of the Société d'Encouragement des Arts, &c. We must refer to the original source for details, but it may be mentioned that the mixed filings fall on two cylinders placed one above the other, and furnished with rings of soft iron, which are rendered magnetic by strong artificial horse shoe magnets of iron, placed as radii. Effective arrangements are made in order to render active the entire surface of the cylinders, and a brush of pig's bristles detaches the adherent filings. It is stated that the separation proceeds very well, and that a machine not costing more than £60 is capable of cleaning half a ton of filings per day. Judging from the description, however, we should be inclined to give preference to the machine used at Quebec, which has already been noticed in a former report.

Reducing Iron Ores with Lignite.—The importance of the question as to the possibility of smelting iron ores economically, by means of the, geologically speaking, younger carboniferous deposits of such as the brown coals and lignites (which, in many parts of the world otherwise altogether deficient in true coal, as we are accustomed to call the mineral of carboniferous age, are found as immense deposits), is probably not fully appreciated in this country where we are so abundantly supplied with the real article, yet it is a question which is attracting more and more attention on the Continent. Under the head of Greece, we have briefly alluded to some trials made in order to smelt the Seriphos brown hematites with the tertiary lignites of Koumi, which experiments cost a large sum of money and turned out a complete failure, but attempts to use a mixture of lignites with the coke in the blast furnace appear, recently, to have been, at least in some instances, more successful; thus we find in the *Kaernthn. Zeitschr.*, for 1875, p. 135, an account given by E. Heygrowsky of trials made at the Zeltweg blast furnaces, which proved that it was possible to replace up to 40 per cent. of the cokes by raw brown coal from Fohnsdorf, with the result that the Bessemer pig produced in the furnace was not only about 10s. per ton cheaper, but also was somewhat purer than when made with the cokes alone, the author considering that when using lignite it is very important to have a wider furnace with a strong and highly heated blast; much more tar is, however, deposited in the gas tubes, which require to be so arranged that they can easily be cleaned out.

We also learn from the *Oesterr. Zeitschr. fur Berg.*, 1875, s. 120, that some experiments have lately been made at the Proevali Iron Works, in order to smelt the Huettenberger brown hematite, in a Siemens rotary furnace, with lignite, but the result was altogether unsatisfactory in an economic point of view, the product being in part useless, full of slag, and not by any means uniform. Trials made by adding to the charge of the coke blast furnace as much as 33 per cent. of the lignite from Lieschaer, appeared, however, to work tolerably well.

In the *Berg und Huettenmaennische Zeitung* for last year, No. 24, will be found a communication treating more at length upon the same subject by R. Von Reichenbach, in which, after giving a summary of the experiments and proposals already made by Gersdorff, Wagner, Mietsch, Khern, Siemens, and others, he suggests that further trials should be

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made on the following plans: (1) with the older lignites, by employing a comparatively low blast furnace with an extremely hot blast to prevent the coal sintering; (2) with the more recent lignites, by first drying them so as to expel all moisture and chemically combined water, and use them as above; (3) by further attempts at coking the lignites; (4) in cases where there are large quantities of very small coal, to use this for the reduction of the ore in one furnace or part of a furnace, and afterwards smelt it by the coarse coal; (5) and lastly, to smelt the iron ores by the gases produced from the lignites in generators.

Still more recently our attention has been directed to the *Berg und Huettenmaennische Zeitung* for the 11th June this year, in which M. A. Kerperly communicates a description of a furnace recently patented by L. Nessel, of the Friedrich's Furnaces, at Rokitzan, in Bohemia, for smelting iron with brown coal or lignite.

Manganiferous and Phosphoric Pig Iron.—An exhaustive paper, by M. H. Le Chatelier, has appeared in the *Annales des Mines*, vol. 6, p. 216-244, for 1874, entitled "Notes taken during a tour in Belgium, on the manufacture of cast irons, containing manganese and phosphorus at the same time, and on their employment in the manufacture of fine-grained wrought iron." The production of good wrought iron at the works of Ougrée, Grivegnée, Dolhain, and l'Espérance, in Belgium, from iron ores containing from 1 to 2 per cent. of phosphorus, which amount is afterwards in great measure expelled in the operation of puddling, and the part played by manganese in this operation, has been carefully studied by M. Le Chatelier, whose experiences are given at some length, and whose paper is well worth perusal by all interested in the subject.

Natural Gas as Fuel.—The success attendant upon the employment of the natural gas from boreholes in several parts of Pennsylvania, as has been alluded to in previous reports, has encouraged a large number of trials being made to extend its application. At Apollo, the whole of the heating furnaces and steam boilers of the ironworks are now kept supplied with natural gas from a well sunk to the depth of 1,250 feet in search of it, and it is said that a combination of ironmasters, consisting of Messrs. Lewis, Bailey, Dalzell & Co., Spang, Chalfant & Co., and Graff, Bennett & Co., have acquired the Butler gas well, and are about to convey the gas in pipes, the distance of some twenty miles, in order to use it at their ironworks. In March, Messrs. Spang, Chalfant & Co. were still boring for gas in their works at Pittsburgh, as also were Messrs. Reis, Brown & Berger, of Newcastle, who had already got down some 1,800 feet. In Ohio, also, the Niles Iron Company were putting down a gas well, as they are called, at their rolling mills at Niles, but the attempt made at the Leetonia Iron Works had been abandoned after getting down 1,500 feet.

Mechanical Puddling.—A communication by Dr. Durre, of Aix la Chapelle, relative to the advances made in mechanical puddling with special reference to the use of the Pernot furnace, illustrated by drawings of the furnace of Pernot, Spencer, and Howson and Thomas, has appeared recently in the *Zeitschrift de Vereines deutscher Ingenieure.* After a short review of the results obtained up to date in the furnaces of Danks, Sellers, Crampton, Howson & Thomas, Spencer & Pernot, the author expresses himself in favor of the last-named furnace, principally for the reasons that the mechanical motion is more favorable to the work itself, and the furnace bed is more easily fitted and accessible during the operations, whereby the production of smaller blooms can be more easily managed.

Ehrenwerth's Rotary Puddling Furnace.—The *Bulletin du Musée de l' Industrie* contains a description of this furnace, from which the following is abstracted: It consists of a revolving hearth fixed on a vertical shaft, and formed of a cast iron bottom and a flange plate. The entrance of air to the furnace is prevented by a cylinder of sheet iron, fixed to the hearth or flange plate, and dipping into an annular trough in which water continually circulates. The mode of cooling the sides of the furnace

differs according as this cylinder is fixed to the hearth or flange plate; in the former instance, the sides being hollow, the cold water is led under pressure in pipes to the hollows, and the flow takes place in the trough above the lower edge; whilst in the latter case the water is forced against the sides of the hearth in small jets crossing one another, and then runs into the trough. Motion is communicated to the hearth shaft by means of a pair of cog wheels driven by a belt from the main shaft.

The heating of the furnace may be by an ordinary fire grate or by gas, and when it is charged, the hearth is put in motion at the rate of 20 to 24 revolutions per minute, and as soon as the pig begins to melt it is worked about with rabbles provided with peels placed obliquely. These rabbles, which have a notch so as to rest on cones in the furnace doors, are moved from the edge of the furnace to the centre and back again, either by hand or by engine power. By placing these peels at two contrary angles, one works the iron which is being puddled towards the interior of the furnace, and the other towards the exterior, so that, by the combination of these movements, with the rotation of the hearth itself, the molten metal is kept in continual agitation.

The balls are made by the puddler as usual, the hearth being only made to revolve from time to time, when one ball is ready, so as to place a fresh quantity of metal before the working door. In order to bring the balls to as uniform a temperature as possible, the hearth is again rotated, the balls returned, and taken out and shingled as usual. The slag in the furnace is then tapped out through two inclined holes left in the flange plate, or it may be ladled out.

One furnace, having two working doors, into which from 15 to 20 tons pig iron are charged at a time, requires four puddlers to work it or three puddlers and a stoker, if the metal is worked by engine power.

Flattening Plate Iron.—In the Bay State Iron Works, at Boston, U. S., a very simple method for flattening plate iron can be seen in use; a heavy roller, worked by machinery, rolls over the plate, which is brought opposite to it; this roller is propelled by a rack and pinion, and, after moving over the plate, it is reversed and rolls back to its original position. In this instance, an old plate roll, with the coupling ends and part of the journey turned off, forms the roller weight employed.

Definition of Steel.—In the *Revue Universelle* and in the first and third of this year's numbers of the *Annuaire de l'Association des Ingenieurs sortis de l'Ecole de Liége*, we find the discussion still continued as to the true signification of the term steel, which commenced when Mr. Greiner, the head of the steel department of the Seraing works (whose name by a typographical error is spelt Gruner in our second report for 1873), defined steel to be any malleable product of the iron industry obtained in a state of fusion, an opinion to which Mr. Hackney, in his paper on the steel manufacture, read lately before the Institution of Civil Engineers, also subscribes; but as this would oblige us to class soft iron made by the Bessemer process, or pure iron cast in a crucible, as steel, although neither of these products will receive a temper, which from the oldest times has been looked upon as the all-characteristic property of steel, we do not think Mr. Greiner's definition is likely to meet with universal acceptance.

Annealed Spiegeleisen.—As it is well known that the objection to the use of spiegeleisen in the production of the extra soft steel and Bessemer iron made by the Bessemer process is the high amount of carbon which it contains, for which reason ferro-manganese is always preferred in such cases, Professor Raymond has proposed in a paper read before the American Institute of Mining Engineers in February, to employ instead of the ordinary spiegeleisen such as had previously been annealed, or more properly speaking decarbonized, by heating it for a considerable time with iron scale in a closed receptacle, just as is done in the ordinary process of making malleable iron castings. Experiments were made by keeping an iron box filled with small fragments of German spiegeleisen packed in iron scale from the rolling mill at a red heat for some three weeks, when upon cooling it was found that the carbon was to a very large extent removed

without the oxydation of the manganese having taken place in any sensible degree, the chemical analyses of the substance before and after the process, made by Mr. J. Blodgett Britton, being as follows :

	Spiegeleisen before.	Spiegeleisen after.
Phosphorus	0.079	0.055
Manganese	11.636	10.689
Carbon	3.016	0.499

If the spiegeleisen had been granulated or cast in thin plates, or had it been of the quality rich in manganese such as is made at the West Cumberland Iron and Steel Works or the Société Anonyme des Hauts-Fourneaux de Marseilles, the results would no doubt have been even more favorable, but at all events they tend to show that the high-priced ferro-manganese is likely to find a much cheaper rival in such decarbonized spiegeleisen. The results have been published in the *Engineering and Mining Journal* of New York, for May 15, 1875.

American Bessemer Works and Rolling Mill Plant.—The following details of the Edgar Thomson Company, Limited, situated at Braddocks, eleven miles east of Pittsburgh, U. S., on the main line of the Pennsylvania Railroad, may be of interest as showing the modern arrangements of an American Bessemer steel works and rail mill, considered capable of turning out 200 tons of ingots and 225 tons of rails if rolled in double lengths, or 200 tons if in single lengths, per day of 24 hours.

The total surface area of the entire works is about 106 acres, and, besides being traversed by the Pennsylvania and the Baltimore and Ohio Railroads, has a frontage of 3,300 feet on the Monongahela River.

Buildings.—At present there have been erected :—Cupola house, 107 feet long, 44 feet wide, and 46 feet high ; converting house, 129 feet long, 84 feet wide, and 30 feet high ; blast engine house, 54 feet long, 48 feet wide, and 36 feet high ; boiler house, 178 feet long, 48 feet wide, and 18 feet high ; gas generator house, 90 feet long, 46 feet wide, and 26 feet high ; rail mill, 380 feet long, 100 feet wide, and 25 feet high, with a wing 100 feet long, 35 feet wide, and 17 feet high ; office and shop buildings, 200 feet long 60 feet wide, and 18 feet high ; and coal and iron store, 40 feet long, 20 feet wide, and 10 feet high. All these buildings have iron roofs, and are constructed wholly of brick except the generator house and rail mill, which have iron side columns with timber side framing.

The converting appliances comprise three cupolas each forty feet high and five feet internal diameter ; two 12 ton cupola ladles upon scales ; two 5 ton converters, fifteen feet high by six feet internal diameter ; twelve crane ladles for casting ; and a full supply of ingot moulds and flasks for bottom casting. Ample stove capacity is provided for drying the spare converter bottoms, flasks, and ladle stoppers. A crusher and mixing mill is in the cupola house, in which there is abundant room for storing the refractory materials intended for immediate use.

The steam machinery is worked by sixteen tubular boilers, each 5 feet diameter and 15 feet long with forty 4½-inch tubes, a separate grate 5½ feet wide by 7 feet long, and a separate chimney 2½ feet internal diameter by 75 feet high ; the boilers are fed by two duplex pumps, 10 inch by 5½ inch with 10 inch stroke, each having a direct cold water supply, and also a connection with either one of the two heaters, which are of the largest size, and supply the boilers with hot filtered water ; each boiler has an independent lined safety valve, feed valve, and blow off valve, and can be used or repaired independently of the others. For the converters, the two blowing machines have 42 inch cylinders with 4 feet stroke ; each has two 20 ton fly-wheels of 20 feet diameter, a balanced slide valve on the steam cylinder, and rubber faced poppet valves on the air cylinder ; the moving parts are balanced by an auxiliary piston in a small steam cylinder. A duplex engine is used for the cupolas with 18 inch steam cylinder, 60 inch air cylinder, and 3 feet stroke. A horizontal engine, 18 inch cylinder by 2 feet stroke, drives the crushing and grinding machinery. Another horizontal engine, 36 inch diameter of cylinder by 4 feet stroke, with a 50 ton fly wheel of 25 feet diameter, drives the blowing mill, whilst a similar engine 46 inch diameter by 4 feet stroke, drives the rail mill. A 3 ton steam hammer is used

for cutting the blooms and for any hot chipping needed; an engine, 16 inch cylinder by 12 inch stroke drives the rail saws, and another, of 18 inch by 2 feet stroke, the straightening presses, slotting machines, and drills for the fish-plate holes.

The hydraulic machinery comprises:—one duplex pressure pump with 25 inch steam cylinders, 9 inch water plungers and 2 feet stroke, and one pressure pump, 20 inch and 7¼ inch by 15 inch stroke; a complete distributing apparatus, all valves of which are connected to a common platform; two accumulators, 16½ inch diameter by 9 feet stroke; a ladle crane, 15½ inch diameter by 6 feet stroke; four cranes, 13 inch diameter by 9 feet stroke, of which three are for lifting ingots and one for the bottom casting flasks; two cylinders, 18 inches diameter by 9 feet stroke with racks and pinions for rotating the converters; one cylinder 12 inch diameter by 2 feet stroke, fixed on a car, for lifting and removing the bottoms of the converters; and two lifts, 9 inch diameter by 27 feet stroke, for raising materials in the cupola house.

The heating furnace plant includes twenty gas generators arranged in five blocks, a sheet iron cooling tube leading overhead to the brick gas flue, and six Siemens furnaces, each 8 feet wide by 20 feet long internal measurement, the chimneys being two in number, each 6 feet diameter by 98 feet high. Three of these furnaces have hydraulic machinery for charging the ingots as brought in red hot from the converting house, and also for drawing them for rolling mill plant. The ingots are bloomed in a 30 inch three-high mill, which is fitted with feeding rollers driven by an independent engine, and with hydraulic cylinders for moving the roller tables, for turning over the ingots, and for moving the middle roller to vary the sizes of the grooves as required. A "telegraph" leads to the steam hammer, and a steam crane piles up the ingots in the yard, whenever it is inconvenient to take them direct to the reheating furnaces for the roll-train. A 23 inch three-high train is used for rolling rails with three sets of rolls. A line of driven rollers leads to the saw carriage, and a second line of driven rollers to a 60 feet straightening plate. Space is provided for a swinging saw for cutting double length rails, and the hooks for handling the rails and rolls are provided with a power lifting apparatus to secure greater rapidity of working.

The water supply is brought from the river through 20-inch glazed sewer piping into a well at which two duplex pumps, each 20 inch by 7½ inch and 15 inch stroke are placed, and an 8 inch pipe from these pumps discharges into a 20,000 gallon tank from which supply pipes are laid on to the works.

A complete system of 30 inch gauge railway tracks go all round the works, and a store room, laboratory, and engineer's offices are to be found in the same building with the machine shop, which latter contains a 54 inch lathe for roll turning, one 30 inch and one 16 inch lathe, a 30 inch planing machine, two drills, a pipe a screw-cutting machine, all driven by an engine of 12 inch cutter and diameter by 18 inch stroke.

We may, in conclusion, mention that a short description, with plan and elevation of the blooming mill engine at these works, will be found in the number of *Engineering* for January 22d, 1875, p. 70, and in the number for March 12, p. 206, is given a plate and description of the Bessemer blooming engine.

Steel Rails Containing Phosphorus.—According to the *Moniteur Industrielle Belge*, the South Austrain Railway Company made in February an attempt at the manufacture of steel rails, by the employment of Terre-noire ferro-manganese, using for this purpose a mixture of pig iron and old rails from Styria which contained about one-six-thousandth part of phosphorus. The proportions actually used were: Praevalie pig iron 21, Praevalie old iron rails 24, Hermannshuette old iron rails 65, and Terre-noire ferro-manganese (containing 50 per cent. manganese) 2 per cent. of the whole. The resulting steel still contained 3½ thousandths part of phosphorus, but allowed itself to be rolled into rails with perfect ease. On this subject, a paper by M. Thiéblemont, the Engineer of the Saint Louis blast furnace, will be found in the *Bulletin de la Société Scientifique Industrielle de Marseilles*, vol. ii., p. 235, for 1874, entitled

"Le Fer et le Phosphore au point de vue Métallurgique," and may be referred to as containing some interesting remarks.

Carburation of Iron.—At the meeting of the Academie des Sciences, on the 5th April, M. Boussingault brought forward a communication on this subject in answer to the questions as to whether iron in the state of cast iron or steel is really in combination with the carbon, and in what proportions, or, in other words, what is the limit of carburation? The results of the most careful analyses show the amount of carbon in carburetted iron to be in variable proportions; thus steel may contain as low as one or two thousandths part, or from seven to ten thousandths, or as much as from ten to fifteen thousandths in hard steel. In cast iron the contents of carbon may vary from two to four per cent., and, exceptionally, even 5 per cent., but it is difficult to determine exactly how much, since the carbon is usually estimated in analyses by difference, and both cast iron and steel often contain manganese, silicon, phosphorus sulphur, and chromium, besides carbon; still the mean of the results gives 4.4 per cent. carbon in cast iron. If the pig iron is gray it is owing to its having, during its cooling, allowed the carbon to separate out in the state of graphite; but M. Boussingault, contrary to the generally received opinion, does not admit any sensible difference between the amount of carbon contained in white as compared with gray iron, and considers that, if any real combination between the iron and carbon is to be admitted, the proportion is as five equivalents of iron to one of carbon, and declares that, however high the temperature may be, there cannot enter more than five per cent. of carbon into the iron.

Carbon in White Cast Iron.—MM. Schuetzenberger and Bourgeois in the *Compt. Rend. de. l'Academie des Sciences* for April 5, 1875, communicate a paper on this subject. A quantity of white cast iron in coarse powder was treated with a solution of sulphate of copper precisely as in Ullgren's process for the determination of carbon in pig iron; the mixture of carbon with copper which resulted was then washed and treated in the cold with a moderately concentrated solution of perchloride of iron mixed with hydrochloric acid. The copper dissolved rapidly, and a black brown powder remained behind, which, after washing with hydrochloric acid and water, and drying at 100°, yielded on analyses:

Carbon	64.00
Water	26.10
Silicious ash	8.10
Matters not determined	1.80
	100.00

100 grammes of this white cast iron afforded by this method 7.135 of the dry black residue. The weight of the crystalline graphite amounted to 1.2 per cent. of this residue, and the determination of the combined carbon by Boussingault's method showed 63.1 per cent. carbon in the residue, and the sum of the combined carbon and graphite being 64.3, approaches very near to 64, the amount found by combustion. Deducting the silicon and other impurities, therefore, the authors conclude that the carbonaceous residue is in reality a hydrate of carbon; when heated to 250° it immediately loses its water without swelling up.

Gas Analysis.—In *Frezenius Zeitschrift fur Analyt. Chemie*, 1875, p. 47, will be found a paper by Stoeckmann on the method of analyzing the gases from blast furnaces, generators, &c., in full detail; the main points of which consist in the combustion with oxyde of copper and determination of the carbonic acid and water so found; determination of the original carbonic acid by means of potash and soda lime; of the heavy carburetted hydrogens by sulphuric acid and combustion of the remaining gases (CO, C_2H_4, H) and calculation of the several constituents; measuring the nitrogen, which, after the combustion with oxyde of copper, is collected unchanged. For details, however, we must refer to the original communication.

Estimation of Sulphur in Coal, Coke, &c.—*The American Chemist*, No. 8, for 1875, gives a process proposed by Mr. S. D. Hayes, the State Assayer for Massachusetts, for determining the amount of sulphur contained in coal, coke, pyrites, gunpowder, &c., as follows:—One gramme of the substance in fine powder is mixed with an equal quantity

of pure lime in a platinum crucible of about 9 centimetres diameter and 13 centimetres in height, and is brought to the consistence of paste by the addition of a sufficient quantity of distilled water, and constant stirring with a short glass rod, taking great care that every particle of the substance comes in contact with the lime solution. The crucible is now placed on a thick cast-iron plate over a Bunsen's gas-burner, and as soon as the mass is seen to be dry, it must be broken up to coarse powder and heated in a muffle to bright red heat for about twenty minutes, during which time all the carbon will be burnt away. The crucible is now allowed to cool, and then about 3 cubic centimetres of a concentrated solution of nitrate of ammonia is added, taking care not to add the solution too quickly, as loss might occur from the energetic action of the caustic lime on the ammonia salt. The whole mass is again heated to dryness and kept some five minutes at a red heat, is then allowed to cool, and dissolved in dilute hydrochloric acid, after which the sulphur in the solution can be determined in the ordinary manner by precipitation as sulphate of barium. A slight modification of this process is now much in use in the United States, which consists in adding to one gramme of the finely powdered substance, contained in a platinum crucible, about 4 or 5 times its bulk of a strong solution of pure soda in alcohol, and after a few minutes, adding, by degrees, 4 or 5 grammes pure slacked lime, stirring up the whole with a strong platinum wire until it has the consistence of paste, but adding no water, the rest of the process is the same as before described, except that sometimes nitrate of soda may be at once added, in which case the heating with nitrate of ammonia is not necessary.

THE PRIMING OF STEAM BOILERS.

From "The Engineer."

It is announced that the boilers of the Serapis on the voyage from Malta to Brindisi gave no trouble by priming, and that the ship attained a speed of thirteen knots. What steps have been taken to bring about this happy result we are unable to say. Possibly nothing was done, and this being the fact, we have the whimsical character, if we may use the words, of priming brought very prominently before us. We have already referred to the boilers of the Serapis; the whole subject of priming is, however, of sufficient importance to claim some further notice.

What in common language we call a steam engine, really consists of two machines—one for producing steam, the other for converting a part of its heat energy into mechanical power—and if we accept the statement that only one heat-unit in ten existing in the fuel is utilized as mechanical power, we must attribute a very large proportion of this enormous loss to that inefficient apparatus called a steam boiler. It is not probable that any very radical improvement in the engine itself lies hidden in the future, as all in fact that can be done by it is to deliver the steam or other gaseous matter after it has passed through the machine, at the lowest possible temperature, and by the simplest possible mechanical arrangements, or those which involve the least losses of heat by radiation, &c., and the minimum of useless work done in friction. The boiler, however, stands in a very different predicament; wasteful as it is in a high degree, even when in its best types and conditions—the causes of its waste are so patent that it is not so much for the philosopher as for the practical mechanic to devise the modes by which its wastefulness may be sensibly reduced without the introduction of cumbrous, inconvenient, or dangerous adjuncts; three points mainly being held in view, namely, that the fuel shall be perfectly burned to carbonic acid and water, that it shall be so burned without the introduction of a much larger volume of at-

mospheric air than is necessary to oxydize the fuel, and lastly, that the gaseous products of combustion shall pass away at a temperature not greatly exceeding that of the water in the boiler. There are other evils, however, belonging to existing forms of boilers, some of which are second only in importance to wastefulness; foremost amongst which are the danger of explosion, and the near cousin of this, the irregularity of action known as priming, to the last of which we confine our remarks here. We need not stop to describe in any general manner to our readers in what priming consists. Every one connected with the construction or working of boilers is but too familiar with the fact that the water within occasionally plays the most capricious pranks, part of it being forced in some more or less divided form and mixed with the steam, out of the boiler and into the engine. Beyond this bare description we fear it is not within the power of the best informed to give any more exact definition of this irregularity, accompanied by a lucid and complete explanation of the physical conditions which are essential to its production. It occurs with every known form of boiler worked with every sort of water, fresh or salt, and while in many cases it may be merely a nuisance unexpectedly and capriciously recurring, there are cases, more especially in marine boilers, in which its occurrence at all may be attended with the most disastrous results. Unexpected priming may cause a steamship to run upon a lee shore, or an ironclad to become unmanageable at the moment she is going into action, and, in the locomotive engine, may eventuate in delay or collision. We have had examples, comparatively recently, in the twinship Castalia obliging the remaking of her boilers, and still later in the troop ship Serapis, the priming of whose boilers seemed likely to mar the punctuality of the Prince of Wales' pageant in India.

Now it is a very remarkable fact that serious as are the inconveniences of this irregularity in the working of steam boilers, long as it has been known, and frequently as it is recorded as recurring both on land and at sea, almost nothing is as yet accurately known as to the physical conditions of which it is the result, and by consequence scarcely anything is prescribable scientifically for its remedy when it is found to occur. It is a branch of steam engineering which may be said to possess as yet no literature, and naturally so, for it has never yet received that searching and full investigation from the physicist which alone can rescue it from the state of confusion in which it is left by practical men, who, if they can manage to get rid of the immediate difficulty by any means, even though that be the substitution of a new boiler, are content, and care nothing about generalizing or even accurately recording the phenomena that have perplexed them. There is indeed no want of scattered communications on the subject to be found in mechanical journals, too often showing a puerile ignorance of what priming is, or how it is produced, and sometimes being the pseudo-scientific vehicle for advertising some nostrum which, being put into the boiler, shall relieve all its internal complaints. But amongst the treatises specially devoted to the construction and management of engines and boilers, whether published in English or French, nothing, so far as we know of, will be found giving us any exact and scientific information upon this not unimportant subject; the only English work that we can recall to memory which professes to treat the subject at all systematically is Armstrong's "Steam Engine Boilers," and his chapter of four or five pages only, gives no record of observed facts, which, when duly classified, must be the only solid basis for theoretic conclusions here as everywhere else, while the theoretic matter of which it does consist is little more than an unpleasant farrago of words without knowledge. What else can we say of an author who invokes J. Scott Russell and the theory of solitary waves of translation to explain the movements of the water within a common cylindrical boiler, having the fireplace at one end and the steam exit at the other, and imagines that out of the tumult of these waves a theory of priming can be extracted? The subject is incidentally treated also by Wilson in his more recent "Treatise on Steam Boilers," but although he avoids the pseudo theories of the first-named author, he has added little or nothing to

previous knowledge, and made no advance towards bringing the obscure phenomena of priming within the grasp of genuine science. Almost no experiments framed with scientific precision have been made upon the subject. Many years ago the well sunk through the sand at Camden Town Station, and intended to supply with water all the locomotive engines there, was found to yield a liquid which produced obstinate priming in the boilers. It was submitted for analysis to the late Master of the Mint, Dr. Graham, and also to the late Dr. Ure, and proved to contain free alkali—uncombined carbonate of soda—to the extent of about 1,160 grains in 100 gallons. Dr. Graham attributed the priming to its presence, and recommended the neutralizing the effect of the alkali by the addition of rather less than its equivalent of hydrochloric or sulphuric acid. This was tried in engines running to Watford and Berkhampstead, and with apparent success, but the experiments, of which some account will be found in the Minutes of the Institution of Civil Engineers, vol. viii., though apparently made under the superintendence of Mr. McConnell, were of a very incomplete and unsatisfactory description, and failed to throw any light upon why the presence of 11.6 grains of carbonate of soda to the gallon should produce priming, or why its conversion into sulphate of soda should prevent that. Indeed, how little real knowledge exists as to how this phenomenon is affected by the presence or absence of foreign matters in the water of the boiler is abundantly evident by the contradictory nostrums which have been recommended from time to time for the prevention of priming, or the contradictory causes which have been propounded as producing it. Thick and unequal incrustation, whether from sea or fresh water, has been assigned as a cause; while others have affirmed that new and perfectly clean boilers frequently prime badly, and yet lose this vice as incrustation gradually accumulates. Any film or coating of the interior of the boiler which interferes with perfect contact of the water has been held as a cause; while the internal coating of the plates with tallow has been held a protection for marine boilers against corrosion, and has not been supposed to produce priming, and the coating the interior with black lead, as well as the throwing of tallow and soap into the water, has been supposed to prevent priming; while, on the other hand a greasy condition of the interior of new locomotive boilers has been assigned as the cause of their priming, which has been also supposed to arise from the rapid steam-generating power attributed to the perfectly clean plates of new fire boxes. A number of other substances besides tallow, soap, &c., have at one time or another been declared panaceas for the malady, such as bran, chaff, horse dung, peat, "brewers' bottoms," angular pebbles, clay, &c., of all of which we can only say, on analogical grounds, that whatever admixture with the water may tend to facilitate the formation and escape of the steam bubbles formed at the heating surface of the boiler, *may* tend to diminish priming. That they can produce any other effect seems at least extremely doubtful.

A few, but very few, leading conditions tending to produce priming may be viewed as sufficiently—though as yet far from clearly or fully—known to warrant our making them the standpoint for experiment and research. Were the production of steam and its consumption by the engine perfectly equable, the supply of steam well within the limits of the boiler's power, and the rise of the steam from the water unimpeded, it would be difficult to see how priming should be possible. It is easy to see that steam may be generated so fast in proportion to the surface of separation of the steam from the water in a boiler, that its volume so far exceeds the means of escape that it must drive much of the water up bodily before it, just as in boiling water by applying heat to the end of a narrow glass tube the water is blown out by the violence of ebullition. This indicates that the "forced" working of a boiler is incompatible with immunity from priming, and that the first condition for preventing the latter is so amply to proportion the boiler, that the greatest volume of steam to be demanded of it shall be produceable without forcing, and by the passage of a fixed number of heat units per second through a unit of heating surface. Thus in the very large boilers used upon the Cornish

system with slow combustion, priming is almost unknown. The consumption of steam is, however, not equable. It is for an instant nothing at the change of stroke, and is not even equal in equal times during the stroke, or that portion of it before the steam is cut off. This involves inequalities in the tension of steam in the boiler keeping time with the stroke of the engine ; and this inequality of tension again involves inequality in the rate of production and escape of the steam from the water. These inequalities are greater, other circumstances being the same, as the capacity of the cylinder is greater in proportion to the steam space in the boiler. A small bubble of steam in the act of forming at a heating surface of the boiler, and which would uniformly expand until its volume became sufficient for its detachment from the heating surface, and rise through the water, is by any reduction in the efflux of steam or increase of tension in the same, kept longer in contact with the heating surface, and when the tension is rapidly reduced it rushes upwards through the fluid with increased velocity, and may carry more or less of the water above its normal surface ; and these phenomena will be more marked as the alternations of tension are more brusque and their range greater. And if the form and condition of the boiler be such that oscillations of the water thus originated can keep rhythmical time with the strokes of the engine or alternate cuttings off and emission of steam, the whole mass of water may surge at intervals far above its normal level, as carried up by the steam. We can thus see that, given the pressure at which the engine is to work, the capacity of the cylinder and that portion of it preceding the cut-off, and the piston velocity, we ought to be able to calculate for a given construction of boiler what must be the minimum steam space, such that the oscillations of tension within the boiler shall not reach the limit at which priming commences. But the foundation for any such calculation must consist in experiment made upon the large scale of actual work, and repeated for each distinct construction of boiler. For it is obvious that one of the conditions consists in the greater or less facility with which the steam as it is generated can escape from the water, and this will vary with the construction of the boiler, which may be such that from this cause alone priming may take place without reference to alternations of steam tension or insufficiency of steam space to bring those alternations within the necessary limits. These two conditions—which may be said to be purely dynamic, and are probably the most important that belong to this complex subject—can never be reduced to scientific law and practical rules except by an elaborate and costly train of experiments made upon boilers of working magnitude, and of the several types most necessary for the usual applications of steam power, as usually employed ; and the object seems to be one of sufficiently wide importance to warrant the expenditure of public money upon them, both for the production of the necessary apparatus and for the payment of some one competent physicist, who, in conjunction with an equally competent mechanical engineer, should be entrusted with the experiments and with the discussion and publication of their results. That there are many subordinate conditions of a more or less purely physical, and so far obscure character—obscure, because as yet never accurately experimented upon and scientifically discussed —admits of no doubt, and they should also be investigated. Amongst these are differences in the state of the interior or evaporative surfaces, of foreign bodies in the water, whether in solution or in suspension; and these would comprehend a complete collection of the facts or supposed facts which are already on record, and their classification into the false and the true, with an elightened discussion of the latter. Why certain fluids within vessels of certain substances should always boil convulsively, which, though a fact well known, is as yet scarcely explained. Thus, sulphuric acid cannot be concentrated in glass vessels owing to this jumping at intervals, without risk ; and platinum stills have been resorted to. Strong alkaline solutions jump in boiling in the same way, and several salts in solution produce like effects. At what degree of dilution with water these effects cease is not ascertained. But the primary facts requiring elucidation appear to be—what minimum

steam space must we have with a given type of boiler and given conditions of working, so that priming shall not be an inevitable mechanical necessity? We might add to the inquiry this—what modifications might advantageously be made in accepted types of boilers, so as to allow the freest possible extrication of the steam from the water? And in this part of the inquiry it would be necessary to take into account any movement communicated to the boiler itself. Thus, there can be little doubt that the great tendency to prime in cylindrical marine boilers is partly due to the increased oscillation of the water itself, which is caused powerfully to surge about by the form of these boilers and the movements of the vessel.

Our object has been here rather to direct attention to the importance of this problem, and to distinguish between the essential and the less important conditions involved in its solution, than to throw any new light upon the problem itself, which we believe can only be done by a large train of precedent experiments. Such experiments as are needed will never be made by the British Association, or other learned societies, committees, or other devices for the joint stock accumulation of knowledge, with nobody in particular responsible. If worthy of being made as a national object—which we hold such an experimental research to be—let it be conducted by some one or two well-remunerated men, responsible for the results which their prior reputations shall warrant, and with means and appliances provided from public sources, just as the laws of the relations between steam pressure and temperature which now govern the physicists and engineers of the world were experimentally ascertained by M. Regnault.

MODERN SANITARY SCIENCE—A CITY OF HEALTH.*

From "Nature."

It is my object to put forward a theoretical outline of a community so circumstanced and so maintained by the exercise of its own free will, guided by scientific knowledge, that in it the perfection of sanitary results will be approached, if not actually realized, in the co-existance of the lowest possible general mortality with the highest possible individual longevity. I shall try to show a working community in which death, if I may apply so common and expressive a phrase on so solemn a subject—in which death is kept as nearly as possible in its proper or natural place in the scheme of life.

Before I proceed to this task, it is right I should ask of the past what hope there is of any such advancement of human progress. For as my Lord of Verulam quaintly teaches, "The past ever deserves that men should stand upon it for awhile to see which way they should go, but when they have made up their minds they should hesitate no longer, but proceed with cheerfulness." For a moment, then, we will stand on the past.

From this vantage-ground we gather the fact, that onward with the simple progress of true civilization the value of life has increased. Ere yet the words "Sanitary Science" had been written; ere yet the heralds of that science, some of whom, in the persons of our illustrious colleagues Edwin Chadwick and William Farr, are with us in this place at this moment; ere yet these heralds had summoned the world to answer for its profligacy of life, the health and strength of mankind was undergoing improvement. One or two striking facts must be sufficient in the brief space at my disposal to demonstrate this truth. In England, from 1790 to 1810, Heberden calculated that the general mortality diminished one-fourth. In France, during the same period, the same favorable returns were made.* The deaths in France, Berard calculated, were 1 in 30 in the year 1780,

* An address by Dr. B. W. Richardson, F. R. S., at the Brighton meeting of the Social Science Association.

and during the eight years from 1817 to 1828, 1 in 40, or a fourth less. In 1780, out of 100 new-born infants in France, 50 died in the two first years ; in the latter period, extending from the time of the census that was taken in 1817 to 1827, only 38 of the same age died, an augmentation of infant life equal to 25 per cent. In 1780 as many as 55 per cent. died before reaching the age of ten years ; in the later period 43, or about a fifth less. In 1780 only 21 persons per cent. attained the age of 50 years ; in the later period 32, or eleven more, reached that term. In 1780 but 15 persons per cent. arrived at 60 years ; in the later period 24 arrived at that age.

Side by side with these facts of the statist we detect other facts which show that in the progress of civilization the actual organic strength and build of the man and woman increases. Just as in the highest developments of the fine arts the sculptor and painter place before us the finest imaginative types of strength, grace, and beauty, so the silent artist, civilization, approaches nearer and nearer to perfection, and by evolution of form and mind develops what is practically a new order of physical and mental build. Peron—who first used, if he did not invent, the little instrument the dynamometer, or muscular strength measurer—subjected specimens of different stages of civilization to the test of his gauge, and discovered that the strength of the limbs of the natives of Van Dieman's Land and New Holland was as 50 degrees of power, whilst that of the Frenchmen was 69, and of the Englishmen 71. The same order of facts are maintained in respect to the size of body. The stalwart Englishman of to-day can neither get into the armor nor be placed in the sarcophagus of those sons of men who were accounted the heroes of the infantile life of the human world.

We discover, moreover, from our view of the past, that the developments of tenacity of life and of vital power have been comparatively rapid in their course when they have once commenced. There is nothing discoverable to us that would lead to the conception of a human civilization extending back over two hundred generations ; and when in these generations we survey the actual effect of civilization—so fragmentary, and over-shadowed by persistent barbarism—in influencing disease and mortality, we are reduced to the observation of at most twelve generations, including our own, engaged indirectly or directly in the work of sanitary progress. During this comparatively brief period, the labor of which, until within a century, has had no systematic direction, the changes for good that have been effected are amongst the most startling of historical facts. Pestilences which decimated populations, and which, like the great plague of London, destroyed 7,165 people in a single week, have lost their virulence ; jail fever has disappeared, and our jails, once each a plague spot, have become, by a strange perversion of civilization, the health spots of, at least, one kingdom. The term Black Death is heard no more ; and ague, from which the London physician once made a fortune, is now a rare tax even on the skill of the hard worked Union Medical Officer.

From the study of the past we are warranted, then, in assuming that civilization, unaided by special scientific knowledge, reduces disease and lessens mortality, and that the hope of doing still more by systematic scientific art is fully justified.

I might hereupon proceed to my project straightway. I perceive, however, that it may be urged, that as mere civilizing influences can of themselves effect so much, they might safely be left to themselves to complete, through the necessity of their demands, the whole sanitary code. If this were so, a formula for a city of health were practically useless. The city would come without the special call for it.

I think it probable the city would come in the manner described, but how long it would be coming is hard to say, for whatever great results have followed civilization, the most that has occurred has been an unexpected, unexplained, and therefore uncertain arrest of the spread of the grand physical scourges of mankind. The phenomena have been suppressed, but the root of not one of them has been touched. Still in our midst are thousands of enfeebled human organisms which only are comparable

with the savage. Still are left amongst us the bases of every disease that, up to the present hour, has afflicted humanity.

The existing calendar of diseases, studied in connection with the classical history of them, written for us by the longest unbroken line of authorities in the world of letters, shows, in unmistakable language, that the imposition of every known malady of man is coeval with every phase of his recorded life on the planet. No malady, once originated, has ever actually died out; many remain as potent as ever. That wasting fatal scourge, pulmonary consumption, the same in character as when Cœlius Aurelianus gave it description; the cancer of to-day is the cancer known to Paulus Eginæta; the Black Death, though its name is gone, lingers in malignant typhus; the great plague of Athens is the modern great plague of England, scarlet fever; the dancing mania of the Middle Ages and convulsionary epidemic of Montmartre, subdued in its violence, is still to be seen in some American communities, and even at this hour in the New Forest of England; smallpox, when the blessed protection of vaccination is withdrawn, is the same virulent destroyer as it was when the Arabian Rhazes defined it; ague lurks yet in our own island, and, albeit, the physician is not enriched by it, is in no symptom changed from the ague that Celsus knew so well; cholera, in its modern representation, is a more terrible malady than its ancient type, in so far as we have knowledge of it from ancient learning; and even that fearful scourge, the great plague of Constantinople, the plague of hallucination and convulsion which raged in the fifth century of our era, has, in our time, under the new names of tetanoid fever and cerebro-spinal meningitis, been met with here and in France, and in Massachusetts has, in the year 1873, laid 747 victims in the dust.

I must cease these illustrations, though I could extend them fairly over the whole chapter of disease, past and present. Suffice it if I have proved the general proposition, that disease is now as it was in the beginning, except that in some examples of it it is less virulent; that the science for extinguishing any one disease has as yet to be learned; and that, as the bases of disease exist, untouched by civilization, so the danger is ever imminent, unless we specially provide against it; that the development of disease may occur with original virulence and fatality, and may at any moment be made active by accidental or systematic ignorance.

I now come to the design I have in hand. Mr. Chadwick has many times told us that he could build a city that would give any stated mortality, from fifty, or any number more, to five, or perhaps some number less, in the thousand annually. I believe Mr. Chadwick to be correct to the letter in this statement, and for that reason I have projected a city that shall show the lowest mortality.

I need not say no such city exists, and you must pardon me for drawing upon your imaginations as I describe it. Depicting nothing whatever but what is at this present moment easily possible, I shall strive to bring into ready and agreeable view a community not abundantly favored by natural resources, which, under the direction of the scientific knowledge acquired in the past two generations, has attained a vitality not perfectly natural, but approaching to that standard. In an artistic sense it would have been better to have chosen a small town or large village than a city for my description; but as the great mortality of states is resident in cities, it is practically better to take the larger and less favored community. If cities could be transformed, the rest would follow.

Our city, which may be named *Hygeia*, has the advantage of being a new foundation, but it is so built that existing cities might be largely modeled upon it.

The population of the city may be placed at 100,000, living in 20,000 houses, built on 4,000 acres of land—an average of twenty-five persons to an acre. This may be considered a large population for the space occupied, but, since the effect of density on vitality tells only determinately when it reaches a certain extreme degree, as in Liverpool and Glasgow, the estimate may be ventured.

The safety of the population of the city is provided for against density by the character of the houses, which ensure

an equal distribution of the population. Tall houses overshadowing the streets, and creating necessity for one entrance to several tenements, are nowhere permitted. In streets devoted to business, where the tradespeople require a place of mart or shop, the houses are four stories high, and in some of the western streets where the houses are separate, three and four storied buildings are erected; but on the whole it is found bad to exceed this range, and as each story is limited to 15 feet, no house is higher than 60 feet.

The substratum of the city is of two kinds. At its northern and highest part there is clay; at its southern and south-eastern gravel. Whatever disadvantages might spring in other places from a retention of water on a clay soil, is here met by the plan that is universally followed, of uilding every house on arches of solid brickwork. So, where in other towns there are areas, and kitchens, and servants' offices, there are here subways through which the air flows freely, and down the inclines of which all currents of water are carried away.

The acreage of our model city allows room for three wide main streets or boulevards, which run from east to west, and which are the main thoroughfares. Beneath each of these is a subway, a railway along which the heavy traffic of the city is carried on. The streets from north to south which cross the main thoroughfares at right angles, and the minor streets which run parallel, are all wide, and, owing to the lowness of the houses, are thoroughly ventilated, and in the day are filled with sunlight. They are planted on each side of the pathways with trees, and in many places with shrubs and evergreens. All the interspaces between the backs of houses are gardens. The churches, hospitals, theatres, banks, lecture-rooms, and other public buildings, as well as some private buildings such as warehouses and stables, stand alone, forming parts of streets, and occupying the position of several houses. They are surrounded with garden space, and add not only to the beauty but to the healthiness of the city. The large houses of the wealthy are situated in a similar manner.

The streets of the city are paved throughout in the same material. As yet wood pavement set in asphalt has been found the best. It is noiseless, cleanly and durable. Tramways are nowhere permitted, the system of underground railways being found amply sufficient for all purposes. The side pavements, which are everywhere ten feet wide, are of white or light gray stone. They have a slight incline towards the streets, and the streets have an incline from their centres towards the margins of the pavements.

From the circumstance that the houses of our model city are based on subways, there is no difficulty whatever in cleansing the streets, no more difficulty than is experienced in Paris. That disgrace to our modern civilization, the mud-cart, is not known, and even the necessity for Mr. E. H. Bayley's roadway movable tanks for mud sweepings (so much wanted in London and other towns similarly built) does not exist. The accumulation of mud and dirt in the streets is washed away every day through side openings into the subways, and is conveyed with the sewage to a destination apart from the city. Thus the streets everywhere are dry and clean, free alike of holes and open drains. Gutter children are an impossibility in a place where there are no gutters for their innocent delectation. Instead of the gutter, the poorest child has the garden; for the foul sight and smell of unwholesome garbage, he has flowers and green sward.

It will be seen, from what has been already told, that in this our model city there are no underground cellars, kitchens, or other caves, which, worse than those ancient British caves that Nottingham still can show the antiquarian as the once fastnesses of her savage children, are even now the loathsome residences of many millions of our domestic and industrial classes. There is not permitted to be one room underground. The living part of every house begins on the level of the street. The houses are built of a brick which has the following sanitary advantages:—It is glazed, and quite impermeable to water, so that during wet seasons the walls of the houses are not saturated with tons of water, as is the case with so many of our present residences. The bricks are perforated transversely, and at the end of each there is a wedge opening, into which no

mortar is inserted, and by which all the openings are allowed to communicate with each other. The walls are in this manner hôneycombed, so that there is in them a constant body of common air let in by side openings in the outer wall, which air can be changed at pleasure, and, if required, can be heated from the fire-grates of the house. The bricks intended for the inside wall of the house, those which form the walls of the rooms, are glazed in different colors, according to the taste of the owner, and are laid so neatly that the after adornment of the walls is considered unnecessary, and, indeed, objectionable. By this means those most unhealthy parts of household accommodation, layers of mouldy paste and size, layers of poisonous paper, or layers of absorbing color stuff or distemper, are entirely done away with. The walls of the rooms can be made clean at any time by the simple use of water, and the ceilings, which are turned in light arches of thinner brick, or tile, colored to match the wall, are open to the same cleansing process. The color selected for the inner brickwork is gray, as a rule, that being most agreeable to the sense of sight; but various tastes prevail, and art so soon ministers to taste, that, in the houses of the wealthy, delightful patterns of work of Pompeian elegance are soon introduced.

As with the bricks, so with the mortar and the wood employed in building; they are rendered, as far as possible, free of moisture. Sea-sand containing salt, and wood that has been saturated with sea-water, two common commodities in badly-built houses, find no place in our modern city.

The most radical changes in the houses of our city are in the chimneys, the roofs, the kitchens, and their adjoining offices. The chimneys, arranged after the manner proposed by Mr. Spencer Wells, are all connected with central shafts, into which the smoke is drawn, and, after being passed through a gas furnace to destroy the free carbon, is discharged colorless into the open air. The city, therefore, at the expense of a small smoke rate, is free of raised chimneys and of the intolerable nuisance of smoke. The roofs of the houses are but slightly arched, and are indeed all but flat. They are covered either with asphalt, which experience, out of our supposed city, has proved to last long and to be easily repaired, or with flat tile. The roofs, barricaded round with iron palisade, tastefully painted, make excellent outdoor grounds for every house. In some instances flowers are cultivated on them.

The housewife must not be shocked when she hears that the kitchens of our model city, and all the kitchen offices, are immediately beneath these garden roofs; are, in fact, in the upper floor of the house instead of the lower. In every point of view, sanitary and economical, this arrangement succeeds admirably. The kitchen is lighted to perfection, so that all uncleanliness is at once detected. The smell which arises from cooking is never disseminated through the rooms of the house. In conveying the cooked food from the kitchen, in houses where there is no lift, the heavy-weighted dishes have to be conveyed down, the emptied and lighter dishes upstairs. The hot water from the kitchen boiler is distributed easily by conducting pipes into the lower rooms, so that in every room and bedroom hot and cold water can at all times be obtained for washing or cleaning purposes; and as on every floor there is a sink for receiving waste water, the carrying of heavy pails from floor to floor is not required. The scullery, which is by the side of the kitchen, is provided with a copper and all the appliances for laundry work; and when that is done at home, the open places on the roof above make an excellent drying ground.

In the wall of the scullery is the upper opening to the shaft of the dust-bin. This shaft, open to the air from the roof, extends to the bin under the basement of the house. A sliding door in the wall opens into the shaft to receive the dust, and this plan is carried out on every floor. The coal-bin is off the scullery, and is ventilated into the air through a shaft, also passing through the roof.

On the landing in the second or middle stories of the three-storied houses there is a bath-room, supplied with hot and cold water from the kitchen above. The floor of the kitchen and of all the upper stories is slightly raised in the centre, and is of smooth gray tile; the

floor of the bath-room is the same. In the living-rooms, where the floors are of wood, a true oak margin of floor extends two feet around each room. Over this no carpet is ever laid. It is kept bright and clean by the old-fashioned bees'-wax and turpentine, and the air is made fresh and ozonic by the process.

Considering that a third part of the life of man is, or should be, spent in sleep, great care is taken with the bedrooms, so that they shall be thoroughly lighted, roomy, and ventilated. Twelve hundred cubic feet of space is allowed for each sleeper, and from the sleeping apartments all unnecessary articles of furniture and of dress are rigorously excluded. Old clothes, old shoes, and other offensive articles of the same order are never permitted to have residence there. In most instances the rooms on the first floor are made the bedrooms, and the lower the living-rooms. In the larger houses bedrooms are carried out in the upper floor for the use of the domestics.

To facilitate communication between the kitchen and the entrance-hall, so that articles of food, fuel, and the like may be carried up, a shaft runs in the partition between two houses, and carries a basket lift in all houses that are above two stories high. Every heavy thing to and from the kitchen is thus carried up and down from floor to floor and from the top to the basement, and much unnecessary labor is thereby saved. In the two-storied houses the lift is unnecessary. A flight of outer steps leads to the upper or kitchen floor.

The warming and ventilation of the houses is carried out by a common and simple plan. The cheerfulness of the fire-side is not sacrificed ; there is still the open grate in every room, but at the back of the fire-stove there is an air-box or case which, distinct from the chimney, communicates by an opening with the outer air, and by another opening with the room. When the fire in the room heats the iron receptacle, fresh air is brought in from without, and is diffused into the room at the upper part on a plan similar to that devised by Capt. Galton.

As each house is complete within itself in all its arrangements, those disfigurements called back premises are not required. There is a wide space consequently between the back fronts of all houses, which space is, in every instance, turned into a garden square, kept in neat order, ornamented with flowers and trees, and furnished with playgrounds for children, young and old.

The houses being built on arched subways, great convenience exists for conveying sewage from, and for conducting water and gas into, the different domiciles. All pipes are conveyed along the subways, and enter each house from beneath. Thus the mains of the water-pipe and the mains of the gas are within instant control on the first floor of the building, and a leakage from either can be immediately prevented. The officers who supply the commodities of gas and water have admission to the sub-ways, and find it most easy and economical to keep all that is under their charge in perfect repair. The sewers of the houses run along the floors of the subways, and are built in brick. They empty into three cross main sewers. They are trapped for each house, and as the water supply is continuous, they are kept well flushed. In addition to the house flushings there are special openings into the sewers by which, at any time, under the direction of the sanitary officer, an independent flushing can be carried out. The sewers are ventilated into tall shafts from the mains by means of a pneumatic engine.

The water-closets in the houses are situated on the middle and basement floors. The continuous water supply flushes them without danger of charging the drinking water with gases emanating from the closet; a danger so imminent in the present method of cisterns, which supply drinking as well as flushing water.

As we walk the streets of our model city, we notice first an absence of places for the public sale of spirituous liquors. Whether this be a voluntary purgation in goodly imitation of the National Temperance League, the effect of Sir Wilfred Lawson's Permissive Bill and most permissive wit and wisdom, or the work of the Good Templars, we need not stay to inquire. We look at the fact only. To this city, as to the town of St. Johnsbury, in Vermont, which Mr. Hepworth Dixon has so graphically de-

scribed, we may apply the description Mr. Dixon has written: "No bar, no dram shop, no saloon defiles the place. Nor is there a single gaming hell or house of ill-repute." Through all the workshops into which we pass, in whatever labor the men or women may be occupied—and the place is noted for its manufacturing industry — at whatever degree of heat or cold, strong drink is unknown. Practically, we are in a total abstainers' town, and a man seen intoxicated would be so avoided by the whole community, he would have no peace to remain.

And, as smoking and drinking go largely together, as the two practices were, indeed, original exchanges of social degradations between the civilized man and the savage, the savage getting very much the worst of the bargain, so the practices disappear largely together. Pipe and glass, cigar and sherry-cobbler, like the Siamese twins, who could only live connected, have both died in our model city. Tobacco, by far the most innocent partner of the firm, lived, as perhaps it deserved to do, a little the longest; but it passed away, and the tobacconist's counter, like the dram counter, has disappeared.

The streets of our city, though sufficiently filled with busy people, are comparatively silent. The subways relieve the heavy traffic, and the factories are all at short distances from the town, except those in which the work that is carried on is silent and free from nuisance. This brings me to speak of some of the public buildings which have relation to our present studies.

It has been found in our towns, generally, that men and women who are engaged in industrial callings, such as tailoring, shoemaking, dressmaking, lacework and the like, work at their own homes amongst their children. That this is a common cause of disease is well understood. I have myself seen the half-made riding-habit that was ultimately to clothe some wealthy damsel rejoicing in her morning ride, act as the coverlet of a poor tailor's child stricken with malignant scarlet-fever. These things must be in the ordinary course of events, under our present bad ordinary system. In the model city we have in our mind's eye, these dangers are met by the simple provision of workmen's offices or workrooms. In convenient parts of the town there are blocks of buildings, designed mainly after the manner of the houses, in which each workman can have a workroom on payment of a moderate sum per week. Here he may work as many hours as he pleases, but he may not transform the room into a home. Each block is under the charge of a superintendent, and also under the observation of the sanitary authorities. The family is thus separated from the work, and the working man is secured the same advantages as the lawyer, the merchant, the banker now possesses; or, to make the parallel more correct, he has the same advantage as the man or woman who works in a factory and goes home to eat and to sleep.

In most towns throughout the kingdom the laundry system is dangerous in the extreme. For anything the healthy householder knows, the clothes he and his children wear have been mixed before, during, and after the process of washing, with the clothes that have come from the bed or the body of some sufferer from a contagious malady. Some of the most fatal outbreaks of disease I have met with have been communicated in this manner. In our model community this danger is entirely avoided by the establishment of public laundries, under municipal direction. No person is obliged to send any article of clothing to be washed at the public laundry; but if he does not send there he must have the washing done at home. Private laundries that do not come under the inspection of the sanitary officer are absolutely forbidden. It is incumbent on all who send clothes to the public laundry from an infected house to state the fact. The clothes thus received are passed for special cleansing into the disinfecting rooms. They are specially washed, dried, and prepared for future wear. The laundries are placed in convenient positions, a little outside the town; they have extensive drying grounds, and, practically, they are worked so economically, that home-washing days, those invaders of domestic comfort, are abolished.

Passing along the main streets of the city we see in twenty places, equally distant, a separate building surrounded

by its own grounds—a model hospital for the sick. To make these institutions the best of their kind, no expense is spared. Several elements contribute to their success. They are small, and readily removable. The old idea of warehousing diseases on the largest possible scale, and of making it the boast of an institution that it contains so many hundred beds, is abandoned here. The old idea of building an institution so that it shall stand for centuries, like a Norman castle, but, unlike the castle, still retain its original character as a shelter for the afflicted, is abandoned. The still more absurd idea of building hospitals for the treatment of special organs of the body, as if the different organs could walk out of the body and present themselves for treatment, is also abandoned.

It will repay us a minute of time to look at one of these model hospitals. One is the *fac simile* of the other, and is devoted to the service of every five thousand of the population. Like every building in the place, it is erected on a subway. There is a wide central entrance, to which there is no ascent, and into which a carriage, cab, or ambulance can drive erect. On each side the gateway are the houses of the resident medical officer and of the matron. Passing down the centre, which is lofty and covered in with glass, we arrive at two side wings running right and left from the centre, and forming cross-corridors. These are the wards: twelve on one hand for male, twelve on the other for female patients. The cross-corridors are twelve feet wide and twenty feet high, and are roofed with glass. The corridor on each side is a framework of walls of glazed brick, arched over head, and divided into six segments. In each segment is a separate, light, elegant removable ward, constructed of glass and iron, twelve feet high, fourteen feet long, and ten feet wide. The cubic capacity of each ward is 1,680 feet. Each patient who is ill enough to require constant attendance has one of these wards entirely to himself, so that the injurious influences on the sick, which are created by mixing up, in one large room, the living and the dying; those who could sleep, were they at rest with those who cannot sleep because they are racked with pain; those who are too nervous or sensitive to move, or cough, or speak, lest they should disturb others; and those who do whatever pleases them; these bad influences are absent.

The wards are fitted up neatly and elegantly. At one end they open into the corridor, at the other towards a veranda which leads to a garden. In bright weather those sick, who even are confined to bed, can, under the direction of the doctor, be wheeled in their beds out into the gardens without leaving the level floor. The wards are warmed by a current of air made to circulate through them by the action of a steam engine, with which every hospital is supplied, and which performs such a number of useful purposes, that the wonder is how hospital management could go on without this assistance.

If at any time a ward becomes infectious, it is removed from its position, and replaced by a new ward. It is then taken to pieces, disinfected, and laid by ready to replace another that may require temporary ejection.

The hospital is supplied on each side with ordinary baths, hot-air baths, vapor baths, and saline baths.

A day sitting-room is attached to each wing, and every reasonable method is taken for engaging the minds of the sick in agreeable and harmless pastimes.

Two trained nurses attend to each corridor, and connected with the hospital is a school for nurses, under the direction of the medical superintendent and the matron. From this school nurses are provided for the town; they are not merely efficient for any duty in the vocation in which they are always engaged, either within the hospital or out of it, but from the care with which they attend to their own personal cleanliness, and the plan they pursue of changing every garment on leaving an infectious case, they fail to be the bearers of any communicable disease. To an hospital four medical officers are appointed, each of whom, therefore, has six resident patients under his care. The officers are called simply medical officers; the distinction, now altogether obsolete, between physicians and surgeons being discarded.

The hospital is brought, by an electrical wire, into communication with all

the fire-stations, factories, mills, theatres, and other important public places. It has an ambulance always ready to be sent out to bring any injured persons to the institution. The ambulance drives straight into the hospital, where a bed of the same height on silent wheels, so that it can be moved without vibration into a ward, receives the patient.

The kitchens, laundries, and laboratories are in a separate block at the back of the institution, but are connected with it by the central corridor. The kitchen and laundries are at the top of this building, the laboratories below. The disinfecting room is close to the engine-room, and superheated steam, which the engine supplies, is used for disinfection

The out-patient department, which is apart from the body of the hospital, resembles that of the Queen's Hospital, Birmingham: the first out-patient department, as far as I am aware, that ever deserved to be seen by a generous public. The patients waiting for advice are seated in a large hall, warmed at all seasons to a proper heat, lighted from the top through a glass roof, and perfectly ventilated. The infectious cases are separated carefully from the rest. The consulting rooms of the medical staff are comfortably fitted, the dispensary is thoroughly officered, and the order that prevails is so effective that a sick person, who is punctual to time, has never to wait.

The medical officers attached to the hospital in our model city are allowed to hold but one appointment at the same time, and that for a limited period. Thus every medical man in the city obtains the equal advantage of hospital practice, and the value of the best medical and surgical skill is fairly equalized through the whole community.

In addition to the hospital building is a separate block, furnished with wards, constructed in the same way as the general wards, for the reception of children suffering from any of the infectious diseases. These wards are so planned that the people, generally, send sick members of their own family into them for treatment, and pay for the privilege.

Supplementary to the hospital are certain other institutions of a kindred character. To check the terrible course of infantile mortality of other large cities —the 76 in the 1,000 of mortality under five years of age, homes for little children are abundant. In these the destitute young are carefully tended by intelligent nurses; and mothers, while following their daily callings, are enabled to leave their children under efficient care.

In a city from which that grand source of wild mirth, hopeless sorrow and confirmed madness, alcohol, has been expelled, it could hardly be expected that much insanity would be found. The few who are insane are placed in houses licensed as asylums, but not different in appearance to other houses in the city. Here they live, in small communities, under proper medical supervision, with their own gardens and pastimes.

The houses of the helpless and aged are, like the asylums, the same as the houses of the rest of the town. No large building for the poor of pretentious style uprears itself; no men badged and badgered as paupers walk the place. Those poor who are really, from physical causes, unable to work, are maintained in a manner showing that they possess yet the dignity of human kind; that, being worth preservation, they are therefore worthy of respectful tenderness. The rest, those who can work, are employed in useful labors which pay for their board. If they cannot find work, and are deserving, they may lodge in the house and earn their subsistence; or they may live from the house and receive pay for work done. If they will not work, they, as vagrants, find a home in prison, where they are compelled to share the common lot of mankind.

Our model city is of course well furnished with baths, swimming baths, Turkish baths, playgrounds, gymnasia, libraries, board schools, fine art schools, lecture halls, and places of instructive amusement. In every board school drill forms part of the programme. I need not dwell on these subjects, but must pass to the sanitary officers and offices.

There is in the city one principal sanitary officer, a duly qualified medical man elected by the Municipal Council, whose sole duty it is to watch over the sanitary welfare of the place. Under him as sanitary officers are all the medical men who form the poor-law medical

staff. To him these make their reports on vaccination and every matter of health pertaining to their respective districts; to him every registrar of births and deaths forwards copies of his registration returns; and to his office are sent, by the medical men generally, registered returns of the cases of sickness prevailing in the district. His inspectors likewise make careful returns of all the known prevailing diseases of the lower animals and of plants. To his office are forwarded, for examination and analysis, specimens of foods and drinks suspected to be adulterated, impure, or otherwise unfitted for use. For the conduction of these researches the sanitary superintendent is allowed a competent chemical staff. Thus, under this central supervision, every death and every disease of the living world in that district, and every assumable cause of disease, comes to light and is subjected, if need be, to inquiry.

At a distance from the town are the sanitary works, the sewage pumping works, the water and gas works, the slaughter-houses and the public laboratories. The sewage, which is brought from the town partly by its own flow and partly by pumping apparatus, is conveyed away to well-drained sewage farms belonging to the city, but at a distance from it, where it is utilized on Mr. Hope's plan.

The water supply, derived from a river which flows to the south-west of the city, is unpolluted by sewage or other refuse, is carefully filtered, is tested twice daily, and if found unsatisfactory is supplied through a reserve tank, in which it can be made to undergo further purification. It is carried through the city everywhere by iron pipes. Leaden pipes are forbidden.

In the sanitary establishment are disinfecting rooms, a mortuary, and ambulances for the conveyance of persons suffering from contagious disease. These are at all times open to the use of the public, subject to the few and simple rules of the management.

The gas, like the water, is submitted to regular analysis by the staff of the sanitary officer, and any fault he may detect which indicates a departure from the standard of purity framed by the Municipal Council is immediately remedied, both gas and water being exclusively under the control of the local authority.

The inspectors of the sanitary officer have under them a body of scavengers. These each day, in the early morning, pass through the various districts allotted to them, and remove all refuse in closed vans. Every portion of manure from stables, streets and yards, is in this way removed daily and transported to the city farms for utilization.

Two additional conveniences are supplied by the sanitary scientific work of this establishment. From steam-works steam is condensed, and a large supply of distilled water is obtained and preserved in a separate tank. This is conveyed by a small main into the city, and at a moderate cost distilled water can be supplied for those domestic purposes for which hard water is objectionable. The second sanitary convenience is a large ozone generator. By this apparatus ozone can be produced in any required quantity, and is made to play many useful purposes. It is passed through the drinking water in the reserve reservoir whenever the water shows excess of organic impurity, and it is conveyed into the city for diffusion into private houses for purposes of disinfection.

The slaughter-houses of the city are all public, and are separated by a distance of a quarter of a mile from the city. They are easily removable edifices, and are under the supervision of the sanitary staff. The Jewish system of inspecting every carcase that is killed is rigorously carried out, with this improvement, that the inspector is a man of scientific knowledge.

All animals used for food—cattle, fowls, swine, rabbits—are subjected to examination in the slaughter-house, or in the market, if they be brought into the city from other depots. The slaughter-houses are so constructed that the animals killed are relieved from the pain of death. They pass through a narcotic chamber, and are brought to the slaughterer oblivious of their fate. The slaughter-houses drain into the sewers of the city, and their complete purification daily, from all offal and refuse, is rigidly enforced.

The buildings, sheds and styes for

domestic food-producing animals, are removed a short distance from the city, and are also under the supervision of the sanitary officer; the food and water supplied for these animals comes equally with human food under proper inspection.

One other subject only remains to be noticed in connection with the arrangements of our model city, and that is the mode of the disposal of the dead. The questions of cremation and of burial in the earth have been considered, and there are some who advocate cremation. For various reasons the process of burial is still retained: firstly, because the cremation process is open to serious medico-legal objections; secondly, because, by the complete resolution of the body into its elementary and inodorous gases in the cremation furnace, that intervening chemical link between the organic and inorganic worlds, the ammonia, is destroyed, and the economy of nature is thereby dangerously disturbed; thirdly, because the natural tendencies of the people lead them still to the earth, as the most fitting resting-place into which, when lifeless, they should be drawn.

Thus the cemetery holds its place in our city, but in a form much modified from the ordinary cemetery. The burial ground is artificially made of a fine carboniferous earth. Vegetation of rapid growth is cultivated over it. The dead are placed in the earth from the bier, either in basket-work or simply in the shroud; and the monumental slab, instead of being set over or at the head or foot of a raised grave, is placed in a spacious covered hall or temple, and records simply the fact that the person commemorated was recommitted to earth in those grounds. In a few months, indeed, no monument would indicate the remains of any dead. In that rapidly-resolving soil the transformation of dust into dust is too perfect to leave a trace of residuum. The natural circle of transmutation is harmlessly completed, and the economy of nature conserved.,

RESULTS.

Omitting, necessarily, many minor but yet important details, I close the description of the imaginary health city. I have yet to indicate what are the results that might be fairly predicted in respect to the disease and mortality presented under the conditions specified.

Two kinds of observation guide me in this essay: one derived from statistical and sanitary work, the other from experience, extended now over thirty years, of disease, its phenomena, its origins, its causes, its terminations.

I infer, then, that in our model city certain forms of disease, would find no possible home, or, at the worst, a home so transient as not to affect the mortality in any serious degree. The infantile diseases, infantile and remittent fevers, convulsions, diarrhœe, croup, marasmus, dysentery, would, I calculate, be almost unknown. Typhus and typhoid fevers and cholera could not, I believe, exist in the city except temporarily and by pure accident; small-pox would be kept under entire control; puerperal fever and hospital fever would probably cease altogether; rheumatic fever, induced by residence in damp houses, and the heart disease subsequent upon it, would be removed; death from privation and from puerpera and scurvy would certainly cease; delirium tremens, liver disease, alcoholic phthisis, alcoholic degeneration of kidney, and all the varied forms of paralysis, insanity, and other affections due to alcohol, would be completely effaced. The parasitic diseases arising from the introduction into the body, through food, of the larvæ of the entozoa, would cease, and that large class of deaths, from pulmonary consumption, induced in less-favored cities by exposure to impure air and badly-ventilated rooms, would, I believe, be reduced so as to bring down the mortality of this signally fatal malady one-third at least.

Some diseases, pre-eminently those which arise from uncontrollable causes, from sudden fluctuations of temperature, electrical storms, and similar great variations of nature, would remain as active as ever; and pneumonia, bronchitis, congestion of the lungs, and summer cholera would still hold their sway. Cancer, also, and allied constitutional diseases of strong hereditary character would yet, as far as we can see, prevail. I fear, moreover, it must be admitted that two or three of the epidemic diseases, notably scarlet fever, measles, and

whooping-cough, would assert themselves, and, though limited in their diffusion by the sanitary provisions for arresting their progress, would claim a considerable number of victims.

With these facts clearly in view, I must be careful not to claim for my model city more than it deserves ; but calculating the mortality which would be saved, and comparing the result with the mortality which now prevails in the most favored of our large English towns, I conclude that an average mortality of eight per thousand would be the maximum in the first generation living under this salutary *régime.* That in a succeeding generation Mr. Chadwick's estimate of a possible mortality of five per thousand would be realized, I have no reasonable doubt, since the almost unrecognized though potent influence of heredity in disease would immediately lessen in intensity, and the healthier parents would bring forth the healthier offspring.

As my voice ceases to dwell on this theme of a yet unknown city of health, do not, I pray you, wake as from a mere dream. The details of the city exist. They have been worked out by those pioneers of sanitary science, so many of whom surround me to-day, and specially by him whose hopeful thought has suggested my design. I am, therefore, but as a draughtsman, who, knowing somewhat your desires and aspirations, have drawn a plan, which you in your wisdom can modify, improve, perfect. In this I know we are of one mind, that though the ideal we all of us hold be never reached during our lives, we shall continue to work successfully for its realization. Utopia itself is but another word for time ; and some day the masses, who now heed us not, or smile incredulously at our proceedings, will awake to our conceptions. Then our knowledge, like light rapidly conveyed from one torch to another, will bury us in its brightness.

By swift degrees the love of Nature works
And warms the bosom, till at last sublim'd
To rapture and enthusiastic heat,
We feel the present Deity, and taste
The joy of God to see a happy world !

ON ROLLING-FRICTION.

By Professor OSBORNE REYNOLDS.

From the Proceedings of the Royal Society.

The motion of a roller or wheel on a surface is always attended with resistance. Coulomb made some experiments with wooden rollers on a wooden plane, from which he deduced two laws, viz. that the resistance is proportional to the weight of the roller, and inversely proportional to its diameter. These laws have since been found to apply to other substances, a different coefficient being used in each case. Beyond this, however, nothing appears hitherto to have been ascertained as regards the nature of this resistance to rolling. The source from which it springs does not appear to have been made the subject of investigation.

Some time ago it occurred to the author that it was probable that the deformation of the surface of the roller and of the plane, which must take place at the point of contact, would affect the distance which the roller would advance in turning through a certain angle. The pressure of the roller on the plane causes a certain temporary indentation and lateral extension in the latter, so that in passing from one point to another the roller does in truth pass over a greater extent of surface than the distance between these points. A simple experiment was sufficient to verify the truth of this conclusion. An iron roller 18 inches in circumference was found to roll through something like $\frac{3}{4}$ inch less than a yard in two complete revolutions when rolling on a plate of india-rubber. The softness of the india-rubber suffered the roller to indent it considerably ; and hence it might be expected that the ef-

fect would be much more apparent than when the roller was rolling on iron or any hard material. At the same time there is doubtless a certain amount of indentation in this latter case; and this will probably cause a similar alteration in the distance rolled through, although too small to allow its being measured.

This falling off from what may be called the geometrical distance, suggested an explanation of the resistance to rolling, namely, that the extension of the surface or surfaces at the point of contact causes the one surface to slide over the other; and this sliding is accomplished against friction. In this way we should expect to find the resistance to rolling greatest under those circumstances in which the sliding is greatest, *i. e.* where the indentation is greatest; and so far it is in accordance with Coulomb's laws. In the case of india-rubber, we find the slipping is very large; and hence we should expect the resistance to rolling to be large also; and accordingly we find it so, for it is more than ten times as great as when the roller is on an iron plane. This very great resistance which india-rubber causes to rolling appears not to have previously caught attention; and yet it is the natural explanation of the invariable failure which has attended the numerous endeavors which have been made to use this material for the tires of wheels.

This idea, that the resistance to rolling is due to the friction between the surfaces sliding at the point of contact, naturally leads to the conclusion that it must depend on the coefficient of friction between these surfaces, and that we might expect to diminish the resistance by using oil or any other means of reducing the coefficient of friction. This was the author's first impression. Experiments, however, showed that the effect of oiling the surface, although it did generally reduce the resistance, was very small; and sometimes it appeared to act in the reverse manner, and increase the resistance. This conclusion or surmise was therefore wrong; and the cause of the error was not far to seek. It consisted in having overlooked the fact that friction not only opposes the sliding of the one surface over the other, but also prevents it to a considerable extent, and thus modifies the deformation which would otherwise take place; so that any diminution in the coefficient of friction is attended with an increase in the extent of slipping, which tends to balance the advantage gained by the reduced coefficient.

The truth of this view derives independent support from a circumstance remotely connected with rolling-friction, of which it furnishes an explanation. When the roller rests on a horizontal surface and is very slightly disturbed, it does not move off, but oscillates backwards and forwards. This happens on all kinds of elastic surfaces; on soft india-rubber the oscillations are both large and continue for some time. Now if the deformation in the surface of the rubber were complete, there would be no tendency to bring the roller back; but since, owing to friction, the india-rubber, under the advancing side of the roller, is prevented from extending while that under the other side is prevented from contracting, there will exist a state of constraint from which the surface is endeavoring to free itself by forcing the roller back.

Besides the relative softness of the materials, the curvature of the roller will affect the lateral extension both of the roller and the plane at the point of contact, so that if the roller and the plane were of the same material there would still be slipping. This would not be the case, however, between two wheels of the same diameter and material rolling in contact.

Such is a short sketch of the subject of the paper, a considerable part of which is devoted to the examination and illustration of the exact manner in which the deformation at the point of contact occurs, and the influence of friction upon it. The latter part of the paper contains an account of numerous experiments, and their results, which were undertaken as part of this investigation.

The first series of experiments relate to the resistance which an iron roller experiences on surfaces of different hardness. Cast iron, glass, brass, boxwood and india-rubber were tried. Extreme care was taken to make the roller and the surfaces true; and this was so far successful that on cast iron the roller would roll in either direction when the

surface had an inclination of one in five thousand, or, roughly, a foot in a mile. Comparing the different surfaces, we see that the resistance increases with the softness, although apparently not in the simple proportion; on boxwood the resistance is nearly double as great as on the harder surfaces, and on india-rubber from six to ten times as great.

The second series of experiments were to ascertain the actual extent of slipping on india-rubber, both with a cast iron roller and also with an india-rubber tire glued on to the roller, and rolled on hard surfaces and on plates of india-rubber of different thicknesses.

These experiments bear out the arguments expressed in the first part of the paper; in fact the arguments were based on the experiments. There is no intention to imply that the whole of the resistance to rolling is in all cases due to the causes already mentioned. Under ordinary circumstances the irregularities of the surfaces and the crushing of the material beneath the roller are the chief causes. And, besides these, two other causes are discussed in the paper as having been brought to light by the experiment, viz. the communication of heat between the compressed material and that which surrounds it, which prevents the material immediately expanding to the same volume as it previously occupied, and the viscosity of the material, which also renders it slow to expand. Both these causes are, however, rather connected with the effect of the speed of the roller on the resistance than with the residual resistance, which, so far as the surfaces are perfectly true and perfectly hard, appears to be due to the friction which accompanies the deformation, and is hence called *rolling-friction*

No attempt has yet been made to investigate the laws of rolling-friction, although the author hopes to continue the investigation in this direction as soon as he has obtained the necessary apparatus.

At the end of the paper attention is called to certain phenomena connected with railway-wheels, which it is thought now, for the first time, receive an explanation. Thus the surprising superiority of steel rails over iron in point of durability is explained as being due as much to the fact that their hardness prevents the wearing-action, *i. e.* the slipping, as that it enables them better to withstand the wear. Also the slipping beneath the wheel explains the wear of the rails in places where brakes are not applied; and the severe lateral extension beneath the wheel is thought to explain the scaling of wrought-iron rails.

LONG STROKE ENGINES.

From "The Engineer."

James Watt, in the course of the not unsuccessful practice of his long life, almost invariably made his engines with a stroke equal in length to twice the diameter of the piston. The engineers, his contemporaries and immediate successors, followed his example very closely; indeed, it was not until the horizontal type of engine came into fashion that short strokes were extensively adopted, except perhaps in marine practice. There is good reason, we think, for believing that Watt was right in preferring long strokes; and that modern engineers are wrong in adopting strokes seldom greater than one and a-half times the diameter of the piston. A great deal may be urged in favor of a long stroke—very little can be said against it. Of course circumstances alter cases; and under peculiar conditions a long stroke cannot possibly be adopted. In dealing with ordinary stationary engines of the horizontal type, however, there is nothing dictated by conditions of space or weight which precludes the adoption of, within reasonable limits, any stroke we please; and we shall show that the arguments which can be urged in favor of long strokes are more weighty and powerful than any that can be urged against them. A

considerable source of loss in all engines is clearance. It is true that if the action of the valves be carefully adjusted to secure the given end, compression may be carried to just such a point at the termination of each stroke that all the vacant space between the piston and the valve will be filled with steam of the same pressure as that just entering from the boiler; but the cases in which this result is secured are not numerous, and it is very doubtful whether the disadvantages entailed by carrying the compression portion of the stroke far enough to secure the stated object do not overbalance the advantage obtained. It is at least certain that very few, if any, engines are worked with maximum economy in which the admission corner of the diagram is not tolerably square and well defined as a distinct angle and not as a curve. When steam is used very expansively, the loss due to clearance is in some measure reduced; but the weight of evidence goes to show that the smaller a clearance space can be made the better. Rankine has given, at pages 418, *et seq.*, of his treatise on the steam engine, an elaborate investigation of the effects of clearance and compression on the efficiency of a given weight of steam when used in an engine, and to this we must refer such of our readers as desire to go more fully into the question. It will suffice to state here that the investigation goes to prove that large clearance spaces are always a source of loss of power, if not of efficiency, even under the most favorable circumstances. It may, in a word, be assumed as granted that the smaller the clearance spaces in any engine the better. Now the amount of clearance may be taken as being, in all cases, a function of the diameter of the piston, and of it alone, because the safety space which must intervene between the piston and the cylinder lid at the termination of each stroke is almost a constant quantity for all engines, large and small. In a marine engine with a 100 in. cylinder ¾ in. clearance is ample, and as little as ½ in. is not unusually met with. In a small engine, say, with a 25 in. or 30 in. cylinder, the distance allowed for clearance cannot be much less. If, then, the diameter of the piston determines the volume of the clearance space, it is evident that the smaller the piston for a given power the better. Thus, of two engines, one with a stroke of 6 ft. and the other with a stroke of 3 ft., the loss caused by clearance will be twice as great in the latter as in the former, other things being equal. It sometimes happens, however, that a single short slide valve only is used with long stroke engines. In such a case port space forms a considerable but illegitimate item in estimating clearance. But long stroke engines should always be worked with a valve at each end, by which means very short ports can be secured; there is no practical difficulty in the way, and we have consequently no right to saddle the long stroke engine with a defect which is introduced by the designer, and is in no way inherent in the type of engine.

A second point in favor of the long stroke engine, and one of much importance, is that the longer the stroke the smaller are the dead or unproductive strains to which the machine is exposed. Thus, with an engine having a 6 ft. stroke and piston 3 ft. in diameter, the strain on the crank pin, when it is at or about the dead point, will, with a total initial pressure of 80 lb., be 81,440 lb. An engine of the same power with a stroke of 3 ft., working under similar conditions of pressure and expansion, and number of revolutions, would exert a dead strain of 162,880 lb. Consequently, in the first place the frictional resistance of the journals and crank pin would be doubled; and, in the second place, they would be still further augmented by the fact that both the crank pin and the main bearing of the crank shaft would have to be of greater diameter than would suffice if the stroke were longer, not, be it understood, because the torsional strain on the crank shaft would be greater in one case than the other, but because the bending moment would be greater. We should then have at each dead point, and in fact throughout the whole stroke, not only a heavier pressure on the bearings, but that pressure would operate with a leverage augmented with the diameter of the shaft and the crank pin, and the *useful* work of the long stroke engine would consequently be greater than that of the short stroke engine. It is obvious that the framing, the piston, and many other

portions of the engine would also have to be made much more strongly than would be required with a long stroke. A third advantage proper to the long stroke is that the action of a steam jacket in securing economy is greater as the diameter of the cylinder is smaller. It is well known, indeed, that the jacket does little good when applied to large cylinders, its influence apparently not being able to extend far into a great body of steam. The condensing area of the piston—which is seldom jacketed—is also reduced by reducing the diameter. The fourth and last point that we shall at present urge in favor of the long stroke engine is that it is much easier to secure efficient action of the valve gear with it than with its short stroke rival.

Thus, if we cut off steam at one-sixth, in the case of the long stroke engine, the piston must, theoretically, move over a space of 1 ft. before the valve closes, while in the case of the short stroke engine the piston moves but 6 in. Now we may assume that the error in the action of the valves is constant for both engines, and that it amounts to a prolongation of the admission after the proper time to the extent of half an inch of piston stroke; that is to say, from the moment the expansion valve begins to close, until it is closed, the main piston will traverse half an inch, a proposition which presupposes much more efficient valve action than is often met with in practice. Under these circumstances the valve error would be twice as great in effect with the short stroke as with the long stroke engine. With the first it would represent $\frac{1}{72}$ of the whole stroke, with the second only $\frac{1}{144}$. If we bear in mind the effect produced by wear and tear, and vibration, and slack joints, on the best designed valve gear, it will be seen that the advantage possessed by a long stroke is of no mean importance; in fact, a valve gear which will give a very good diagram with a long stroke, may give a wretched card if the stroke of the engine to which it is applied be short. We may conclude our arguments in favor of long strokes by stating that they possess every advantage for working steam expansively with the maximum of economy, and that they entail the minimum amount of frictional resistance, so that not only is the indicated power to be obtained cheaply with them, but the greatest possible percentage of the indicated power is left available for useful purposes.

The only objections which we have ever heard urged against the long stroke engine are two in number. The first is that to obtain the proper number of revolutions the piston speed must be too high; and the second is, that long strokes require an extravagantly long engine if of the horizontal type, or too lofty an engine if the cylinder is vertical. The first point may, we think, be dismissed very speedily. There is no objection to a high piston speed. There is an objection to a rapidity of change in the direction of the strains on the crank pin, pistons, &c. While the piston of an engine of any length of stroke, and running at any velocity, is in mid stroke, there is no noise or jerking or knocking; it is only at the ends of the stroke that there is noise and trouble. If the long stroke engine does not make more revolutions than its rival, it will work as quietly, though with twice the piston speed. If the duration of the strains were always one way there would be no inconvenience in running at any speed we liked. The Brotherhood and Hardingham three-cylinder engine may be cited as an example; we have seen this engine driving a large silent fan at 500 revolutions a minute, and no sound could be heard except the whir of the steam escaping from the blast pipe.

As regards the second, the strains are materially reduced by the adoption of a long stroke; therefore it does not follow that the weight of a bed plate, &c., need be much, if at all augmented in anything like proportion to the increase in its length. But it does not follow that because we have a long stroke we must of necessity have a very long engine. For example, an engine with a three-feet stroke would be, if well proportioned, about 12 ft. 6 in. to 13 ft. long, allowing the connecting rod to be two strokes long. An engine with a six feet stroke, similarly proportioned, would be about 23 ft. over all. Now, in the first place, it has to be shown that there is any valid objection to this increased length, but, assuming for the sake of argument that there is, then the length admits of being reduced by making the connecting

rod shorter. The objection to a short connecting rod is, that it causes great wear of the cross-head and guides ; but it is obvious that we reduce at once the strain on these members of the engine by one-half if we halve the area of the piston ; and, in the next place, we double the extent of surface to be worn out, because the guides will be twice as long with the small piston as with the large. It appears, therefore, that, other things being equal, we may use a practically shorter connecting rod with a long stroke engine than would be admissible with a short stroke engine, and this being the case, if we cut down our connecting rod to one and a-half strokes length instead of retaining two strokes, the engine will be shortened to 20 ft. instead of remaining at 23 ft. This line of argument need only be applied to horizontal engines. We have already shown that with vertical cylinders, by adopting what is known as the "table engine," all objections connected with excessive height are overcome. The best proof that the expedient is satisfactory is supplied by the extended and successful use made of the table engine in driving screw propellers in the United States.

Marine engines are there used with strokes of 6 feet and 7 feet, where English engineers would hesitate to adopt anything in excess of 3 ft. We may add that there is evidence available of a tendency on the part of engineers in this country to adopt longer strokes than were in fashion a few years ago. We can assure such of our readers as are interested in steam engine construction that they will find, on examination, that it is worth while, in all cases, to adopt the longest stroke that can be obtained even with some sacrifice of time and trouble.

THE THERMO-ELECTRIC GENERATOR.

From the "Mining Journal."

Considerable attention was directed some seven years since to an invention for generating electricity by heat, and although, as is usual with all new processes and apparatus, it was found in applying it practically that certain modifications of details were necessary, enough was done to show that the invention was worthy of development, and Mr. Charles Clamond, of Paris, has since succeeded in rendering it as near as may be perfect, thus solving the long-open problem of producing cheap electricity on a large scale. The principle involved in the original invention remains unchanged, but important alterations have been made in the construction of the bars and the method of applying the heat. The difficulties with regard to thermo-electric piles were at first very great, arising chiefly from the thermo-electric bars only retainig their power for a short time. Under the continued action of the heat, and the alternate successive heating and cooling to which the bars are subjected they acquire an interior resistance, which goes on increasing, (although the electric force is the same), and which eventually becomes such that the current engendered by the heat no longer gives more than a very feeble and inappreciable quantity of electricity. Sometimes there is even a complete cessation of the continuity, which renders the electric performance unreliable, perhaps at the moment when it is most required. After careful investigation Mr. Clamond discovered that this defect was was mainly owing to two causes—firstly, the surface of the metallic plate by contact with the metal or crystallized mineral oxydized and became a resistant to the passage ; and, secondly, the crystallized bar, whether metallic or not, became split or cracked. These cracks, imperceptible to the naked eye, grew larger, and the oxydation penetrated to the interior of the bar, which became more and more resistant, which unfavorable circumstance rapidly rendered the pile useless.

By a special method of fastening or sealing the metallic plate in the part of the bar exposed to the heat, combined

with a peculiar method of casting the bars in hot moulds, Mr. Clamond succeeds in getting rid of the difficulties. When the thermo-electric pile is to be constructed he sometimes places all the bars in line, but generally he adopts the circular arrangement. A given number of elements are superposed and isolated one from another by mica or amianthus, forming by their superposition a cylinder, the interior of which has to be heated. A fire-clay tube, with perforations upon its circumference at intervals to form a kind of lengthened cap, is placed within the pile, an air space, open at the top, being left between the tube and the bars. The whole is heated with a Bunsen burner, ordinary coal gas supplied through a regulator being the fuel used. The mixture of the gas and air takes place in the refractory cap, and comes away at different heights through the orifices which lead into the annular space, where it is burnt in contact with the hot air coming from below, the previous heating of the air rendering the combustion very complete. The bars are also heated at the same time by the radiation of the fire-clay tube, which remains at a red heat, and by the contact of the flame and the products of combustion rising towards the chimney. Each bar is furnished with pole-plates for taking up or receiving the electric current. The method of uniting the plates to the electrode depends upon whether it is desired to develop a tension or a quantity current, and also upon the tension and upon the quantity of it. One of the plates may be sealed flatwise, as usual, to the cold end of the bar, the other being in contact with a bar in the interior or hot part.

In the moulding operation the metallic plate first placed in the moulds is provided with a little appendage, which, while the metal is flowing through or into the mould, will be sealed or fastened to the material of which the bar is composed. This appendage is a metallic ring soldered to the plate and formed in a plate somewhat narrower than the plate, or else it is taken even into a part of the plate, which is hallowed for the purpose, another portion being thrown back again and beaten down to double its thickness. The width of the ring should be smaller by about half than that of the plate, these plates, scraped or tinned, being placed in the mould and conveniently arranged. The metal or mineral envelops or surrounds the ring, which penetrates to the interior, constituting thus a core which forms one with the mass of the bar, and which insures an intimate and permanent contact between the plate and the bar. The material preferred for the bars is an alloy consisting of about two parts of antimony with one part zinc.

With regard to the efficient working of a thermo-electric pile, Mr. Clamond maintains that whatever be the substance employed, so long as it is cast in cold moulds it is impossible to prevent it cracking interiorly; that is due to the homogeneity of the crystalline covering, and in consequence of the inequality of the dilitation, which occasions the ruptures and crackings which take place in the bar. On contact with the cold sides or walls of the mould the exterior coating of the melted metal or mineral hardens quickly, and undergoes a kind of hardening which contracts it, while the interior of the bar is still liquid, and is congealed very slowly. It follows, as a natural consequence, that the crystallization is not uniform and regular. Mr. Clamond claims that his method entirely avoids these inconveniences; it consists in previously heating the moulds to a degree very near to the point of fusion of the metal or mineral. These latter, melted to a liquid in the crucible, are poured into the heated moulds, which are placed afterwards in a middle course, where they are allowed to cool slowly. He thus obtains bars which are perfectly homogeneous, and in consequence do not crack or split. For ensuring the proper arrangement of the elements of the pile he supports them between two ring-plates. These ring-plates are bound firmly to the central discs by arms traversed at their extremities by button-rods serving for cross bars. The inferior or lower plate is cast in a piece with the foot supports.

It will readily be understood that gas may not be at all times available for producing heat, but as Mr. Clamond has arranged for the use of coke, in that case the system would seem to be generally applicable. When he heats by coke for generating thermo-electricity

the coke is enclosed in a cylindrical column of iron concentric to the pile, and of a diameter narrower than the interior diameter in order to reserve an annular space between the two for the radiation of the heat. The coke rests upon a fixed or movable bar, which admits of the necessary air for the combustion, the products escaping by a lateral conduit to the chimney. The products can, however, be made to circulate in the space before passing away, To maintain the current continuously the coke (or where the pile is very small, charcoal) is charged at the top, and the residue can be removed by lowering the bars, which, by preference, are jointed.

The invention has already been fairly tested in this country, and the value and economy of the pile for telegraphic purposes have been placed beyond question by the result of many month's working at the Exchange Telegraph Company's office, in Bartholomew House. The Thermo-Electric Generator Company now propose to introduce it more generally, and as it is equally applicable to electro-plating and electrotyping, production of light—and, indeed, to all the various purposes for which batteries are commonly employed—there would appear to be a large field for business. At the recent meeting of the Société d'Encouragement pour l' Industrie Nationale the large gold medal was awarded to Mr. Clamond in recognition and appreciation of the value of his important discovery, and there can be no question that the honor was well deserved. The economy in maintenance is found to be very considerable in comparison with other batteries, and the current obtained is constant and free from polarization and exhaustion. By way of illustration of the efficiency of the pile, it may be stated that when employed for the deposition of metals it was found that a machine of 100 bars, with a consumption of 8 to 9 cubic feet of gas, would deposit about 1 oz. of silver per hour. The same apparatus, coupled for quantity, deposited about the same quantity of copper in a similar time. Another apparatus, with 400 bars, large, consuming 2 lbs. of coke per hour, will deposit about four times those quantities. The invention altogether appears to be a highly valuable one, and the progress made in introducing it will be watched with much interest.

NOTE ON THE DETERMINATION OF THE MAGNETIC MERIDIAN.

By L. WAGONER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

HAVING occasion to determine the magnetic meridian in this place (Porto Alegre, Brazil), and finding a difference of twenty minutes in the results given by two good theodolites, I devised the following described magnetic apparatus, which, from its simplicity and cheapness, can be made useful in many cases :

The magnet or needle is composed of ten pieces of watch spring 100^{mm} long (3.93 in.), 3^{mm} broad, and 0.3^{mm} high, each piece was magnetized separately, and then the ten were bound together with silk thread at each end ; upon the north pole was secured a small silver frame carrying a mirror four-tenths of an inch square. It will be seen that the magnet when completed has a section that is nearly square, and each side is 3^{mm} ($\frac{1}{8}$ in.). The magnet is suspended in a small ring; in the upper part of this ring is a steel pivot upon which the whole swings freely ; the lower side of the ring has two small flat pieces, $\frac{1}{2}$ inch long, soldered upon it to keep the magnet from falling out of the ring. The whole is enclosed in a small wooden box with glass ends, and in the middle of the box is a small cross piece of wood carrying a narrow piece of glass about one-tenth inch broad, and one-half inch long. This piece of glass is parallel to the axis of the box, and the pivot in the ring rests upon the flat surface of the

glass. The mirror is made approximately correct by bending the silver frame until the plane of the mirror is perpendicular to the axis of the magnet, which can be proved with a square or triangle. To use it, set it up in the magnetic meridian and balance the needle in the ring by sliding from one end to the other until it remains level; then look in the mirror, and going backwards a few feet, look for the reflected image of your eye, at the same time by reason of the mirrors being very small you can look on beyond it; there in the line place a flag pole. The magnet is then turned upon each of the remaining three sides, and a similar reading made for each—the mean of the four is the magnetic meridian. But for greater exactness it is better to place the instrument about ten feet from a theodolite, and as nearly in the magnetic meridian as possible, about one foot in front of the theodolite and one foot higher than the telescope. Secure a piece of plank two feet long at right angle to line of sight; this plank is to carry a plumb bob having a cord one-sixteen inch well chalked, so that it may be easily seen; then focus the telescope for double distance of the mirror, and slide the plumb along the board until its reflected image coincides with the cross wires and mark its place; repeat this operation with the other three sides of the magnet in order to eliminate any error in the mirror, and mark the mean of the four readings; then determine the point upon the wood where the cross wires would strike, and also the distance from the mirror to the wooden cross piece; from this data the angle can be found that the axis of the telescope makes with the magnetic meridian. Thus, suppose the distance from mirror to the wood$=$100 inches, the difference of the four readings from the line of sight $= 2$ in., then the angle $= \frac{2}{100\cdot 2} = \frac{1}{100}$ $=0^\circ\ 35'$. The magnet in my apparatus with mirror and ring weighs 82 grains, and has a supporting power of five times its weight. The pivot is a small steel screw ground to angle upon its point of 60° and made very hard. With the telescope a variation of five seconds can easily be seen. The entire cost of the apparatus was about seven dollars.

THE RESOURCES OF EGYPT.

From "Engineering."

We are frequently reproached as a nation with our indifference to Indian affairs, and not without reason, for the average Englishman probably acquires his smattering of Indian knowledge at school and forgets it subsequently along with his mathematics and Greek. Such a change could not be sustained against us as regards Egypt, for there are few countries so well known to Englishmen of all ranks and ages. The height of the Nile even is the subject of numerous telegrams to the London press, but who would care to learn the height of the Sone or Tungabudra, or even know to what rivers those euphonious names apply? The recent unreasoning panic in Egyptian affairs is, therefore, more a matter of surprise than it would otherwise have been, and affords another proof that knowledge apparently sound and extensive is often vague and shallow. The natural wealth and exceptional physical advantages of Egypt have many times been urged by the friends of the country during the recent panic, but until the letter of Mr. Fowler appeared in the *Times* of the 28th ult., no specific facts were adduced which would enable an investor to put an approximate money value to the future resources of Egypt. The required information came the more appropriately from an engineer, since the Khedive himself has adopted an engineering policy in the development of his country, and according to Mr. Fowler arranges with him as his consulting engineer the general scope and leading details of works to be carried out, and provides for a proper competition between the leading manufacturers of the chief European nations.

Mr. Fowler takes a sanguine view of the future resources of Egypt, and al-

though he carefully abstains from imposing his views upon investors he nevertheless submits certain facts, within his own knowledge to their consideration. He points out firstly that a large proportion of the debt of Egypt is due to the construction of gigantic works such as the Suez Canal and Alexandria Harbor, which though not immediately profitable in the commercial sense of the word, were essential to national development—works in short corresponding to the making of roads, the drainage, and other costly preliminary operations, which an ordinary proprietor would undertake for the development of his estate. Further, Mr. Fowler calls attention to the fact that all works of this character required in Egypt are now practically complete and paid for, and that the future expenditure can be restricted to such works as will yield immediate and adequate returns. Improved means of irrigation is evidently in Mr. Fowler's opinion the present requirement of Egypt and the source of its future increased welfare. From recent surveys and investigations Mr. Fowler has been led to the conclusion that 600,000 acres of desert land may be easily and profitably brought under cultivation, and he states that the annual value of the crops on these lands would probably range from 8*l.* to 12*l.* per acre. Again, with a proper system of irrigation the manual labor at present expended in raising water for the lands—the money value of which is equivalent to no less than one-half the crops—would be almost entirely dispensed with. A gradual increase of revenue from the land tax of several millions per annum is thus indicated, and the elevation in the status of the Fellaheen from drawers of water to cultivators of the soil, and the enrichment of all Egyptians, would also follow. It will be interesting to see how far these sanguine anticipations of the Khedive's engineer are justified by the facts.

Egypt is an essentially agricultural country, and in proportion to the area of the land under cultivation, it is rather more densely populated than the United Kingdom. Last year the area under cultivation was at the rate of a little more than one arcre per head of population in the United Kingdom, whilst in Egypt with a population of about one-sixth the acreage was rather less than one per head. The relative productiveness of the land of the two countries is, of course, beyond comparison in favor of Fgypt. In our own country ordinary pasture land constitutes a large proportion of the whole, whilst in Egypt not a piece of turf is to be found unless perhaps in the Esbekieh, or in some of the Palace Gardens. With soil so rich that a heavy crop of Indian corn, and another of wheat, or eight crops of clover may be raised from the same land in a year, a broad expanse of park land is a luxury not to be indulged in.

Perhaps nothing strikes the traveler more on his first visit to Egypt than the thick sprinkling of people which he finds uniformly extending over the whole surface of the country. In England we may travel by rail through hundreds of miles of country, and unless it be in harvest or haymaking time, see nothing more than an occasional ploughman with his team, or a solitary rustic, acting as a scarcecrow to the birds—the only other animated things to be seen. In Egypt, on the contrary, there is a perpetual harvest, and the country "creeps" with people, but the whole of this fertile and populous land would be nothing more than a burnt-up desert, but for one cause, and that is the presence of the Nile.

The extent of the cultivated land is limited only by the line up to which the Nile water travels by inundation canals or otherwise. Those who have passed through the Suez Canal may remember the blossoming little gardens a few feet square at some of the "stations" which look as distinct and independent of the surrounding desert as if the whole garden were simply an extra large box of flowers brought over direct from France in some vessel for the benefit of an expatriated Frenchman. Had our travelers landed they would have found the first cause of these oases on the desert banks of a salt water canal in a little lead pipe, perhaps not one inch in diameter, communicating with a miniature watercourse, in its turn communicating with a small sweet water canal, and had they followed up this canal they would have found, after a journey of 120 miles, that it was the Nile itself which had

transformed the little patch of desert land into a garden.

The same is true of the whole of Egypt. A sharp line as distinct as the color on a map marks the boundary between the bright green of the cultivated land and the sparkling yellow sands of the desert, and the same line serves to mark the limit of the inundation of the Nile. The fertilizing properties of the water are due, says Dr. Letheby, to the notable quantity of ammonia and nitrogenous organic matter contained in solution and to the large amount of sedimentary matters charged with phosphates. There is no other source of water in Egypt than the Nile, for the well waters are simply Nile water robbed of the chief portions of its fertilizing properties and objectionally charged with saline aliments abstracted from the soil. Nile water is at all times turbid, but to a varying degree. At Low Nile the solid matters in suspension amount to but 5 grains per gallon, whilst at High Nile the proportion is 105 grains, or about double the percentage of solids found in average London sewage. The quality of Nile water, therefore, is all that can be desired, but in forming an estimate of the future resources of Egypt, or in other words of the increased productiveness and the extension of area of the cultivated land, it is necessary to be satisfied that there is sufficient water in the river for irrigation purposes, and that it can be conveyed to the desired points.

In June, 1873, the velocity and sectional area of the Nile when at its lowest was measured in a very exact manner, and the results showed a minimum discharge of 12,600 cubic feet per second. The river rarely falls so low as it did in 1873, and the minimum discharge in all years applies but to a few days. Thus a fortnight after the preceding measurements were taken the discharge was found to have more than trebled, and it continued rapidly increasing until the maximum for the year of about 270,000 cubic feet per second was reached. A reference to the statistics of our leading Indian canals will satisfy any one interested that there is an ample supply of water in the Nile at all times of the year for the complete irrigation of all the cultivated lands of Egypt, and of all probable or possible additions to these lands. We must now see how the water is to be got to the land with the least expenditure of labor.

The general fall of the Nile Valley and of the river itself is at the rate of about 5 inch per mile, and the land falls from the river bank towards the desert at the same inclination. A more rapid fall would in some respects have been advantageous, but as the ground is even and easy of excavation, the general conditions are extremely favorable for irrigation works. The level of the land immediately contiguous to the river is about 20 feet above Low Nile, or 3 feet below a good average High Nile. The actual rise of the Nile varies considerably year by year from the 23 feet assumed above. Thus the High Nile of 1868, which was the lowest for many years past, rose but 19 feet, whilst on the other hand the alarmingly high Nile of 1874, rose no less than 28 feet. It is difficult to say which extreme is the most undesirable. When the Nile does not rise to the required height the crops are burnt up, and the land is unproductive over a great extent of country. When the Nile is too high, the water infiltrates through the soil, washes up the salts, and poisons the vegetation, thus involving not merely a loss of the year's crops, but much work to clear the soil for the next year's sowing. During last year's High Nile tens of thousands of men were for some time engaged in raising the river banks, but though the direct overflow of the Nile was thus successfully frustrated, the process of infiltration went on unchecked, and many valuable crops were destroyed.

The irrigation works at present in operation in Egypt may be roughly comprised under two heads, viz., Canals Selfi and Canals Nili, corresponding respectively to the perennial and inundation canals of our Indian nomenclature. In the former canals the depth of water is about 3 feet at lowest Nile, in the latter the depth of excavation is only from 12 feet to 15 feet, and, therefore, the bottom is far above Low Nile. The headworks consist generally of a substantial barrage or brick viaduct with openings from 10 feet to 15 feet wide, closable by vertical planks or sheet piling. At intervals down the canals similar barrages

are placed, by closing which the level of water is raised to a sufficient extent in some instances to inundate adjoining lands, and in others to materially reduce the height to which the water has to be raised by manual labor or otherwise. This system involves considerable work in clearing the canals periodically of sedimentary deposits, which had the flow been constant, would have been carried on to the lands inundated, to the great advantage of the latter. Great improvements have been effected by His Highness the Khedive, and the extension of the irrigation canals alone have, Mr. Fowler states, involved the excavation of 65 per cent. more material than the whole of the Suez Canal. Still in the summer season water is not only scarce but what there is of it has to be raised by sakiehs, or primitive chain pumps worked by buffaloes, by shadoofs, or the still more primitive bucket and balance-beam system, and when the lift is very small by the altoway, which is nothing more than a simple basket swung backwards and forwards by a couple of men. Cornish pumping engines are also to be found on the banks of the Nile. But centrifugal pumps driven by portable engines are far more common. Whichever system of raising water may be in use the cost is a most serious tax upon the land. As a consequence, between May and July much of the land lies fallow, for the ground is too hard to be plowed without previous inundation. From want of water during these months some of the villages are occasionally in a bankrupt state, unable to pay the Government taxes or to obtain necessaries. The whole scene is, however, at once transformed upon the appearance of a portable engine and centrifugal pump, the proprietor of which will perhaps graciously accept one-third or one-half of the produce in return for watering the land three times.

The ordinary charge for watering once is at the rate of 20 francs per feddan, or acre, for land situated close to the pumping station, and as much as 40 francs for land four or five miles distant. It is stated that the loss from infiltration and evaporation renders the last sum the least favorable bargain to the proprietor of the pump. When the water is raised by means of the shadoof each feddan requires the services of two men for about one hundred days, assuming the crop to be doora sefi, or the summer growth of Indian corn.

It will be apparent enough that there is room for a considerable addition to the resources of Egypt, if at the present time from £3 to £6 per acre is expended in watering, which in India would cost but as many shillings in the districts where high level canals have been constructed. All that is required in Egypt is a constant supply of water to the main canals at the same height, and in the same quantity as obtains when the Nile has risen from 12 feet to 15 feet. The measured flow in the Menoufieh Canal, which has a bottom width of 200 feet, with its headworks placed at the apex of the Delta, was but 360 cubic feet per second in June of last year, and no less than 6,300 cubic feet two months later. The minimum flow in this canal should not be less than 4,000 cubic feet per second, which quantity could be well spared from the Nile when at its lowest, and if the level of the water in the river at the intake of the canal could be raised about 14 feet the required quantity would flow down the canal at a sufficient height to irrigate almost the whole of the lands without pumping. The same remark applies to the main canals having their intake at the same part of the river, and irrigating the lands on the right and left banks of the Damietta and Rosetta branches respectively. It was with a view to obtain this desideratum that the grand barrage of the Nile was projected and constructed.

This work may be shortly described as a couple of massively constructed brick viaducts carried across the two branches of the river, and including between them 132 arches or openings of about 16 feet span, the said openings being closeable by iron sluices of somewhat peculiar construction. It was originally intended to back up the water by this structure about 15 feet, but owing to defective foundations it has not been deemed prudent to submit the barrage to a greater stress than that due to a head of 3 feet to 5 feet of water. If the barrage could be completed in an efficient manner the problem of improved irrigation would be to a great extent

solved. The extension and enlargement of a few canals would be all the additional work required to supersede the greater proportion of the costly pumping now going on, and to reclaim a large additional amount of land from the desert.

Our space only admits of a very brief reference to the nature, rotation, and value of the crops grown in Egypt. To illustrate these matters we will cite as an example the practice on an actual estate in the Delta, exactly 1000 acres in extent. This, as regards farming operations, is usually dealt with in three portions, the first of which, 300 acres in extent, is sown with cotton in April, and about nine months subsequently with berseem, or clover. The second portion, 350 acres in area, is sown with doora, or Indian corn, in July, and with wheat or barley about three months afterwards. The remaining 350 acres is for a part of the year under clover and for a certain time fallow. The number of waterings the above crops receive in the year varies from two to eight, and the total is equivalent to a single watering of 6750 acres. It is stated on good local authority that the required supply involves the constant working day and night of a 12 inch centrifugal pump delivering nominally 2000 gallons per minute. Probably five inches in depth would be an ample allowance for each watering, and this, without reckoning waste, would be provided for by an average discharge of 1500 gallons per minute. Upon no less good local authority it is stated that the value of the above crops when raised would average from £12 to £13 per acre.

The facts and figures advanced in the present article will be sufficient to prove that the present produce of the land in Egypt is no measure of her future resources, but that by judiciously designed and economically executed irrigation works, the profitable returns of the land under cultivation may, in many instances, be doubled; whilst an addition, amounting to no mean percentage of the total area of the land may by the same means be reclaimed from the desert.

BAIE VERTE CANAL.

By THOS. GUERIN, C. E.

Written for Van Nostrand's Engineering Magazine.

In the month of September, 1874, I contributed an article to this Magazine on the subject of the "Baie Verte Canal." I find that in the "Transactions of the American Society of Civil Engineers," Second Series, No. 21, there is published a paper contributed by "Clemens Herschel, C. E., Member of the Society," on the same subject. Mr. Herschel commences by asserting that my article "is founded on a gross hydraulic heresy," and then proceeds as follows :

"The first part of the present discussion, which is to prove Mr. Guerin wrong was not difficult; the second part, to show what is the correct solution of his problem, required more time," &c.

"Mr. Guerin's article would be an excellent one were not the very basis of it an illusion. I allude to the assumption that $v=n\sqrt[3]{r}$, where n is a coefficient by Mr. Guerin supposed to be somewhat uniform ; r is the vertical rise of a tidal stream during any length of time t, and v is its mean horizontal velocity during the same time. From two experiments, Mr. Guerin deduces $n = 1.3313$ and 1.3124," &c.

"To test the above enunciated 'principle,' therefore, I have taken data given in Beardmore's Manual of Hydrology relative to the tidal phenomena of the Clyde, those given in Hagen's Waserhaum, Vol. iii., page 161, relative to the tide of the Weser; and, finally, those to be found in the Annals des Ponts et Chausses, 1861, in an article by M. Partiot on the Seine.

"The following are the results compared with the two values of n already given :

"On the Missignash, 1.3313 and 1.3124;

on the Clyde, opposite Glasgow, 34.685; Clyde Bank, 65.407; Bowling, 116.82 and Port Glasgow, 90.03; on the Weser' opposite Flagshalger Siel, 2.504, and on the Seine, 3.612.

"It thus appears that n is not constant for the different parts of the same river nor for any two rivers. In fact there is no such law as $v=n\ {}^3\sqrt{r}$ in tidal streams, for the rise and flow of the tide are far more a matter of the propagation of waves than of flow in a channel."

That is how Mr. Herschel has proved "Mr. Guerin" wrong.

I will now show how unwarrantable the assertions made in the above quotations are, and how erroneous his paper is from end to end. Furthermore, I will show that the authorities he quotes, instead of aiding his views, confirm the conclusions arrived at in the article of mine already referred to.

In the first place, the formula $v=n\ {}^3\sqrt{r}$ is not "an assumption," it is the result of investigation. I have assumed nothing; nor have I asserted anything without demonstrating it.

Again, I have not asserted that "r in the formula is the vertical rise of a tidal stream during any length of time t, and v is its horizontal velocity during the same time." If Mr. Herschel looks again at the investigation he will find that, in arriving at the above formula, the time is a unit, and in finding the value of $n=1.3313$, that unit is one hour.

It can be seen by reading the article, that this value for n is not intended to apply to all rivers nor to "different parts of the same river," if those parts are, themselves, different.

It can be seen that the coefficient sought was obtained for the current of a tide flowing in an even horizontal bed. The River Missiguash was selected for the experiment, at a place about one and a half miles from the sea-shore, and the time selected was at a stage of the tide when it was rising nearly uniformly. The river was in the immediate vicinity of the proposed canal; its bed was reasonably even, and it was shown in the investigation that the inclination of the river was such that it could not affect the velocity of the tidal current so as to make it differ perceptibly from that on a horizontal plane.

The coefficient obtained for the Missiguash cannot materially differ from that obtained for a similar river, and must be reasonably correct for obtaining the velocity of a tidal current flowing in an even horizontal bed such as the summit reach of the Baie Verte Canal; if there is any truth in science. I did not then, nor do I now claim extreme accuracy for this coefficient, and I have therefore suggested to other gentlemen to experiment and verify or amend it if necessary.

Mr. Herschel comes forward, and instead of attempting to verify or correct the value of n under the necessary conditions, has recourse to the tides of the River Clyde as recorded in Beardmore's Manual of Hydrology, and says that the application of the above equation would give those values for n which I have already quoted from his paper. He should have shown how he obtained those values.

Although I do not claim extreme accuracy for the coefficient 1.3313 nor assert its applicability to different rivers; yet, I hold that there is not a tidal river in existence that will give those coefficients which Mr. Herschel states he has obtained for the Clyde from Beardmore's Hydrology.

Now for facts. Beardmore's Manual of Hydrology, to which Mr. Herschel refers as authority, is now before me, and on examining what is stated there respecting the tides of the River Clyde, I find in page 253 that the mean velocity of the flood stream above New Shot Isle is 78.10 feet per minute, and the average velocity below New Shot Isle is 38.56 feet per minute. It must be borne in mind that above New Shot Isle comprises Glasgow and Clyde Bank, while Bowling and Port Glasgow are below.

Referring to the same page of the same book, I find the following statement in reference to the tidal range and duration of flood. The values of r and n, as given on the following page, are computed from this data, and inserted by myself thereunder:

Spring Tides.	Glasgow.	Clyde Bank.	Bowling.	Port Glasgow.
Tidal range............	8 ft. 4″	8 ft. 0″	8 ft. 9″	10 ft. 0″
Duration of flood......	5 h. 10 m.	5 h. 15 m.	5 h. 24 m.	6 h. 6 m.
Value of r............	1.612	1.524	1.620	1.707
n............	0.550	0.558	1.110	1.090
Neap Tides.				
Tidal range............	6 ft. 3″	5 ft. 10″	5 ft. 11″	6 ft. 1″
Duration of flood......	5 h. 14 m.	5 h. 43 m.	5 h. 52 m.	6 h. 26 m.
Value of r............	1.194	1.020	1.008	0.945
n............	0.605	0.630	1.298	1.327

It is necessary to remark here that at the end of Beardmore's Manual of Hydrology there is plate XI. giving a section of the bottom of the River Clyde between Glasgow and Port Glasgow. This section shows the bottom of the Clyde to be of a most jagged description from Glasgow to a point about one mile distant from Bowling. At Bowling it is comparatively even for about two miles. At Port Glasgow the river is fifty feet deep and upwards, so that a tidal current cannot be much interfered with by any irregularities in the bottom.

On examining the values of n in the above table, it can be seen that at Glasgow and Clyde Bank, where the bottom is uneven, $n=0.550$ and 0.558 respectively for spring tides; while at Bowling and Port Glasgow, where the bottom is not so irregular, the values of n are 1.110 and 1.090 respectively. Again, for Neap tides the values of the coefficient n at Glasgow and Clyde Bank are 0.605 and 0.630 respectively; while at Bowling and Port Glasgow the values are 1.298 and 1.327.

From these facts it can be seen that the values of the coefficient n for the River Clyde, at Bowling and Port Glasgow, differ but little from that obtained for the Missiguash; in fact, they are singularly coincident. At spring tides there seems to be a difference of $\frac{2}{10}$ between the Clyde and the Missiguash; but this may have arisen from some extraneous cause, such as a strong wind which often blows at the time of spring tides; or it may have arisen from the mode of observation.

The authorities, "Hagen's Waserbaum" and "The article by M. Partiot on the Seine," I have not at my command; but there is an extract from M. Partiot's article given in Beardmore's Manual of Hydrology (page 267 to 270), where probably Mr. Herschel has sought the information he refers to. Although this extract seems to contain all the observations recorded in the article, yet there is not the proper data in it from which to find the value of n. The only place where an approach to the data even in a loose way can be found is at Quillebeouf; and here, with even such imperfect data, the value of n will be found to differ from that obtained for the Missiguash by a fraction varying from $\frac{53}{100}$ to $\frac{67}{100}$.

If, in the face of such facts as these, Mr. Herschel is still of the opinion that the coefficients for the River Clyde, Seine, &c., are those extraordinary numbers given in his paper, I do not feel bound to take the trouble of dissuading him; but when he attacks an article of mine, using those numbers as his only basis for attack, and publishes to the engineering profession that a formula deduced by me from a mathematical investigation "is wrong" and "is a delusion," then I must correct him.

Admitting that those extraordinary numbers of his had been correctly obtained, it would even then be a matter of great assurance to assert that there is no such law as $v=n\sqrt[3]{r}$, deduced as it was from a mathematical investigation. It should have been shown that the investigation was erroneous before such a sweeping assertion was published among scientific papers.

This gentleman, on having disposed of my article to his own satisfaction, next undertakes "to show what is the correct solution of the problem." He commences with the subject of the propaga-

tion of waves, and at once appeals to a written work by "D'Arcy and Bazin sur la propagation des ondes." He refers to some experiments made by M. Bazin, and in a note* at the bottom of the page he states he does not propose to quote from J. Scott Russell's experiments; nor from the data given in Beardmore's Manual of Hydrology; nor from the purely theoretical paper of the Astronomer Royal, Mr. Airy, though, he says, they all contain much that is of interest.† He further says, he hardly knows whether it will be needful to give proofs of the correctness of the theory of wave propagation, and of the applicability of the same to the case of the Baie Verte Canal. He says: "On the whole it will perhaps be sufficient to refer to the works already cited together with, say David Stevenson's Canal and River Engineering."

Mr. Herschel is manifestly of the opinion that those authorities confirm his belief, that the filling of the Baie Verte Canal from tide water depends on the propagation of a wave. I will refer to those authorities presently, but, first, I must state what is well known to Hydraulic Engineers, that the propagation or velocity of a wave has no connection whatever with the flow or forward advancement of water. When a wave moves in water, there is no current of water accompanying the wave as a consequence of the wave's velocity or propagation. If the wave made by a steamboat moving in a canal or river be observed, it will be seen that, although the wave is moving at a high velocity, yet, if it meet any floating body, such as a piece of wood, the latter is not borne along with the wave; it is simply lifted up; the wave passes under it and the piece of wood is deposited in the spot where it was met at first by the wave. A wave is simply a protuberance moving through the water. The characteristic of a wave is that energy, not matter is transferred in its propagation (see Chamber's Encyclopædia). There is no relation whatever between the propagation or velocity of a tidal wave and that of a tidal current.

In corroboration of what has been just affirmed, I will refer to David Stevenson, to whom reference has been also made by Mr. Herschel.

Mr. Stevenson states in his "Canal and River Engineering" (pages 59 and 60) "But the passage of the tidal wave through an estuary or river must not be mistaken for what is called the tide current, which is a totally different phenomenon." He then states that the tidal wave passes through Dornoch Firth at the rate of 22 miles per hour; but the current flows through the same place with a velocity not exceeding four or five miles an hour.

He further says: "The laws of propagation of the tidal wave to which we first alluded, depends as explained on circumstances somewhat obscure; but the velocity of the tide current, or that current which flows into our rivers and affects the transit of shipping, is due entirely to the slope or fall on the surface of the water. The amount of this slope has been shown to be dependent on the rapidity with which the tide rises, and the amount of obstruction presented to its propagation up the river. The more rapid the rise of the tide and the greater the obstructions to its flow, the higher will the tide wave, at certain parts of a river or estuary be heaped up. A head of water is thus formed whose height is due to the rapidity of the rise of the tide and the obstructions to its progress, and a flow of water having a velocity due to that head is generated up the river or estuary, and this flow of water is what we term the tide current."

A similar explanation to the above is given in my previous article to this Magazine; but in more concise terms. I had not read Mr. Stevenson's explanation before I wrote that article. The conclusions were deduced from actual observation of the phenomena of the tide in the Bay of Fundy while I was engaged by the Canadian Government in surveying the line of the proposed Baie Verte Canal.

Referring to Beardmore's Manual of Hydrology, to which reference is made by Mr. Herschel on the subject of wave propagation, the following statements are made in pages 251 and 253 respecting the tidal wave and tidal stream of the Clyde:

* *Vid.* Transactions of the American Society of Civil Engineers, page 187.
† *Ibid.* Page 188.

	Velocity of wave per minute.	Velocity of stream per minute.
Between Port Glasgow and Bombay..............	1080 ft.	78 ft.
Between Bowling and Clyde Bank.....	584 ft.	78 ft.
Between Clyde Bank and Glasgow..............	1441 ft.	38 ft.

In page 265, River Severn :

	Wave per minute.	Stream.
Between Newnham and Framlode............	1907 ft.	217 ft.
Page 268, River Seine....	1274 ft.	332 ft.

To adduce an example nearer home—the speed of the tidal wave in Chesapeake Bay, from Cape Henry to the head of the Bay is 15 miles an hour, while the tidal current moves at the rate only of one mile an hour.

On reading the above quotations, taken from the authorities referred to, respecting those observed phenomena ; it is manifest there is no relation existing between the velocity of a tidal wave and that of a tidal current or stream. This conclusion is also deducible from the formulæ investigated by Professor Airy, the Astronomer Royal.

The formulæ of Professor Airy are founded, first, on the equation of continuity, which is deduced from the hypothesis of equality existing between a rectangular parallelopiped of water at rest and the oblique parallelopiped formed in disturbed water by the new positions of the light particles constituting the angular points of the former parallelopiped. But as the water is supposed to be in a rectangular canal, the extent of the parallelopiped in the direction of the breadth of the canal is supposed to be constant ; therefore it is sufficient to assume the equality of the parallelograms which form a side of each in the direction of the length of the canal.

The canal being of uniform depth, the equation will be as follows :

$$Y=\int\frac{dX}{dx}$$

(This expression being integrated between O and Y.)

An equation is next found for the pressure on any particle from the forces that act upon it. The equation is expressed as follows :

$$-\frac{d^2y}{dt}=\frac{dP}{dy'}+g$$

Where P is the pressure in every direction on the lower part of a disturbed molecule of water in consequence of the weight of the filament of particles above it.

y' or $y+Y$ is the vertical coordinate of the particle.

dt is the increment of time in which the vertical coordinate becomes $y'+\delta y'$.

g denotes the force of gravity.

This equation is integrated between the limits for the bottom of the molecule and the top of the wave, and there results the hydrostatic force by which a vertical filament descends or moves horizontally. If all extraneous forces, such as the attraction of the sun or moon, on a molecule be represented by F, the equation of motion becomes

$$\frac{d^2X}{dt^2}=F-\frac{dP}{dx}$$

This equation gives a relation between the terms X, Y, x, y, t.

In order to represent oscillatory motion, both the horizontal and vertical displacements are represented by terms containing the sines or cosines of angles depending on the time t.

Let it be assumed that

$$X=R\cos(nt-mx)+S\sin(nt-mx).$$

R and S being functions of y.

Suppose that gravity is constant, and that no extraneous forces act, and that for the present there is retained only the first power of $\frac{dX}{dx}$.

The above equations give

$$\frac{d^2X}{dy^2}+\frac{d^2X}{dx^2}=0$$

From these equations are obtained the values of X and Y in terms of A cos $(nt-mx)$ and B sin $(nt-mx)$.

These values will not be altered if mx is increased or diminished by a whole circumference, that is, if x is increased or dimnished by $\frac{2\pi}{m}$, $\frac{4\pi}{m}$, &c., while t remains constant. Hence $\frac{2\pi}{m}$ is the value of the increments of x which correspond to points where the particles of water are in the same condition with respect to disturb-

ance, that is, $\frac{2\pi}{m}$ is the length of a wave.

By similar reasoning $\frac{2\pi}{n}$ is the period of a wave or the time of two successive formations of a wave summit at the same place. Hence $\frac{n}{m}$ is the velocity of the wave; and from the value found for it by the theory, it follows that the velocity depends on m and on the depth of water; the latter being constant, the velocity depends on the length of the wave; or it depends on the time in which a particle of water makes a complete vibration. If the length of a wave or the time of vibration is given, the velocity will vary with the depth of water.

The foregoing is a brief synopsis of the mode of reasoning pursued by Professor Airy in his paper on "Tides and Waves." Its applicability to the motion of a stream or current of water is apparent.

From these formulæ it is deduced that when the length of the wave is not less than one thousand times the depth of the water the velocity of the wave is equal to $\sqrt{g\,h}$, where g denotes gravity and h the depth of water. Mr. John Scott Russell confirms this formula in his report pursuant to the inquiries made by the British Association.

More generally: if

v=the velocity of a wave;

h=the depth of disturbance of the particles of water;

g=gravity.

There will result:

$v=\sqrt{g\,h}$ even in water of unlimited depth.

$v=\sqrt{\frac{g\,\mathrm{L}}{2\,\pi}}$ is the velocity of a rolling wave in deep water, when L= length of the wave, and π=ratio of circumference to diameter.

From these facts, it is evident there is no analogy or relation existing between the velocity of a current or stream and that of a wave of any description.

Mr. Herschel, in quoting from Bazin's work, says: "If U represent the velocity of the water in the canal behind the wave that is requisite for the delivery of Q, that is, if $\mathrm{U}=\frac{\mathrm{Q}}{\mathrm{W\,H}}$; then when $\mathrm{U}>\sqrt{2\,g\,\mathrm{H}}$ the wave will break up, or, as M. Baron expresses it, 'deferlement' will take place."

It is evident that here M. Bazin is misunderstood by Mr. Herschel, for the reason that no man of the ability of M. Bazin would state such foolish doctrine. "Deferlement" will take place or the wave will break up, when the first portion of the wave is overtaken by the succeeding portion, or "the water in the canal behind the wave," as Mr. Herschel expresses it. It will be remembered that the velocity of the wave is $\sqrt{g\,\mathrm{H}}$, hence U will only require to be greater than this quantity in order to overtake the wave in front and cause it to break up. The wave will, therefore, break up and "deferlement" will take place long before $\mathrm{U}>\sqrt{2\,g\,\mathrm{H}}$. But it appears Mr. Herschel thinks otherwise.

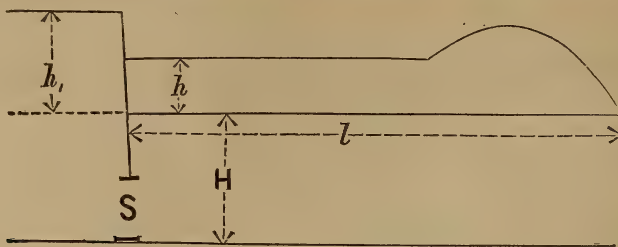
He states he has made three experiments on the Northern Canal at Lowel, in order to ascertain whether the wave gets away fast enough to allow the proper quantity, which would flow through the submerged orifice or sluice of a lock gate to enter the canal. He says the experiments were a test of formulæ and principles already established.

I shall leave the reader to appreciate the motive for which those experiments were made.

The next and final portion of his paper is devoted to the investigation of formulæ for the filling of a canal from tide water.

I shall copy what he says, and I shall number his equations for the sake of reference:

"Take now the case of the Northern Canal in my experiments, or that of the Au Lac Reservoir and Baie Verte Canal. Let H be the depth of the canal when the gates are opened; h the depth of the water above the original level in the canal at any time at which on the outside the water stands h_1 feet above the original canal level, and l the distance which the first wave has traveled since the gates were opened. The problem is to find the value of h and l; having given H, h_1, the effective area S of the



submerged orifice and the width w of the canal.

Approximately

$$l=t\sqrt{g\,\mathrm{H}}=t\,v \quad . \quad . \quad 1°$$

$$h=\frac{Q}{w\,v} \quad . \quad . \quad . \quad . \quad 2°$$

$$Q=S\sqrt{2\,g}\,\sqrt{h_1-h} \quad . \quad 3°$$

$$Q=S\sqrt{2\,g}\quad\sqrt{h_1-\frac{Q}{w\,v}} \,. \quad 4°$$

$$Q=\sqrt{2\,g\,s^2\,h_1+\left(\frac{g\,s^2}{w\,v}\right)^2}-\frac{g\,s^2}{w\,v}\,5°"$$

Although there is no mention made of Q in the above notation, it is evident he intends it to represent the quantity of water which enters the canal through the orifice S in one second.

The velocity of a wave traversing the canal is $\sqrt{g\,\mathrm{H}}$, and this quantity is designated by v (see equation 1°).

From an inspection of the above figure, it is evident that it is allowed that the quantity Q entering the canal through the orifice S increases the depth by h, and flows along the surface of the water in the canal thus generating a current.

Equation 2° contains two errors—one arises from the fact that in it, the canal is assumed to be rectangular, when in reality the sides have a slope of one in two. The second error arises from the fact that in this equation, the velocity of the current generated by Q is assumed to be the same as the velocity of the tidal wave or v: two quantities which have been shown to have no relation whatever.

Equation 3° is erroneous; it should be as follows:

$$Q=m\,S\,\sqrt{2\,g\,(h_1-h)}$$

where m is the coefficient of discharge through an orifice, which can be found in all treatises on hydraulics.

Equation 4° contains all the errors already pointed out.

Equation 5° contains all the previous errors—this is the formula by which he has made his computations.

There are numerous errors in his paper besides these pointed out here.

A mind of ordinary intelligence can see at a glance that his formula is erroneous without going to the trouble of analyzing his paper as I have done. Suppose that in the spring of the year, when navigation is about to be opened, the summit reach of this canal will then require to be filled. At that time there is no water in it, and the height denoted by H is equal to zero. His equation 2° has $h=\frac{Q}{w\,v}$ where $v=\sqrt{g\,\mathrm{H}}$. It follows from this that h is infinitely great; or, in other words, as soon as the water would be let into the canal in the spring, a flood or wave higher than the distance from here to the star Arcturus would rush into the canal as soon as the gate is opened if his formula were true.

The application of his formula to the Baie Verte Canal, based as it is on such error and absurdity, renders every column after the first, erroneous in page 198 of the "Transactions of the American Society of Civil Engineers."

It is almost needless to remark that the figure above, which is copied from Mr. Herschel's paper, gives a false representation of the phenomena that take place during the tidal flow into the canal.

I shall not further discuss Mr. Herschel's paper; but I must say that, considering the apparent industry he has evinced in his attempt at acquiring means by which to attack what I have written in this Magazine, one would almost feel sorry for the fate his exertions have met with here.

The conclusions arrived at in my article of September, 1874, remain unchanged.

ON THE CONDITIONS AND PROSPECTS OF ARCHITECTURE IN THE UNITED STATES.

By WM. FOGERTY, Fellow of the Royal Institute of British Architects.

The importance of travel to the professor or student of architecture is a matter pretty extensively recognized and admitted. Even before the days of steamships and railways, it was considered an essential part of every English architect's education that he should spend a year or more on the continent of Europe, visiting the noble monuments of ancient, mediæval, and modern art to be found there. But, notwithstanding the great facilities of travel alluded to, which have brought America practically as near to us as France or Germany were but a few years since, that continent has not commonly been looked on as by any means a desirable field for similar travel. It has been too generally assumed that there was nothing to be seen or learnt of the art in America, an error which I trust this paper may have some effect in exploding, while at the same time I may be able to point out the peculiar attraction America presents, as being undoubtedly the grandest field the world has ever presented for architectural practice, calculated to awaken the noblest ambition in the breast of every true lover of his art; an ambition too, not by any means likely to be disappointed in those who, having become duly qualified by European study, may not find suitable openings at home, and may choose to transfer the scene of their labors to the New World.

In this latter respect America, and especially the United States, is widely different from the continent of Europe. Of all the English students and architects who annually visit the classic cities of Europe, it is rare to hear of one engaging in actual practice, much less settling in any of them. The number of new and important buildings to be erected is so few in comparison with the amount of local talent, that, although we may now and then hear of an English congregation, in some continental city, getting a design for their church from a London architect, or of an English millionaire employing one of the same fraternity to build a villa on the shores of some Swiss or Italian lake, these instances are so few and exceptional as only to prove the general principle that the continent of Europe, albeit an admirable hunting ground for English engineers, is by no means an attractive field for practice for architects of the same nationality. But it is hard for an English architect of any ability to travel in the United States and not be strongly tempted to settle there. That more have not done so is rather a matter of surprise, possibly to be accounted for by the fearful struggles, political and financial, through which the country has so recently passed, and by the fact that architects are commonly men of quiet and domestic tastes, whose household gods are dear to them, and who, unlike their brethren the engineers, ordinarily prefer modest competence at home to the chances of achieving fame and fortune abroad.

To be sure, a large proportion of the profession in America is composed of men born in the United Kingdom, as is the case there with all other professions and trades. But these men have commonly emigrated while young, and have acquired their profession in America. The number of those who have studied in Europe is comparatively small, and it is to be observed that in most instances they occupy important and leading positions. Of course they are at a slight disadvantage at the outset compared with native Americans, possessed of local knowledge and influence, but this is soon overcome, and they are, or ought to be, possessed of great advantages over the foreigners of other nationalities, French and German for instance, in speaking the same language as prevails in the country of their adoption, and being accustomed to nearly the same laws and social usages. Diversities of this kind, though usually mastered in time by the Germans, seem to present an insurmountable obstacle to the success of our Gallic neighbors in

the practice of architecture in the United States. Architects of other nationalities may be thankful for this, for American taste is so decidedly in favor of everything French, and French ability, I need hardly say, is so strongly marked, that if French architects were only to take kindly to American soil they would soon carry all before them upon it. As things are, however, the field, though wide and open to all nations, is so circumstanced as to invite English-speaking architects more strongly than any others.

These views may seem, at first sight, to be at variance with those expressed in a paper on American practice recently read by me in New York, as it is there stated that architects are neither so much appreciated nor employed in America as in Europe. But this seeming contradiction will be reconciled when the causes are investigated, some of which are dealt with in that paper. I am convinced that the American public only requires to be shown what well-qualified architects really can and ought to do for them, to appreciate and remunerate them correspondingly. But so long as architects there are content, as they are, to neglect the constructive, financial, and executive parts of their profession, and choose to devote themselves almost exclusively to the æsthetic, it is no wonder that so eminently practical a people hold them in slight esteem, and look upon them to a great extent as mere draughtsmen.

With these preliminary remarks I will now proceed to give some account of the condition of the art itself, as shown in the principle buildings, which I will endeavor to describe under their several classes.

Vast as is the territory of the United States, its active life is, I think, more concentrated in cities than in Europe, and it is in them we must look for the best types of American architecture. The smaller country towns and villages can scarcely be said to possess any architecture at all, being often built wholly of wood, in plain box-like forms, or else of brick, used in equally simple forms, and taxing no other resources than those of the local "boss" carpenter or mason. There are but few country mansions on a large scale surrounded with ample demesnes, such as are to be found in Europe, consequent on the absence of a territorial aristocracy. There are, however, in the vicinity of all large cities numerous pretty villas occupied by wealthy merchants and bankers, which bear a close resemblance to the same class of houses in the old country, with some marked peculiarities to be presently noticed. The more common ambition, however, of the American millionaire is to build neither a country mansion nor suburban villa, but to erect for himself a gorgeous town-house on Fifth Avenue, New York, or some of the corresponding streets in other cities. City life is, for various reasons, the most attractive, elegant and fashionable, and hence the town houses, especially of New York, are by far superior to the country or suburban, and compare favorably with those of most European capitals.

Of course, in the wealthy and fashionable quarters, churches of corresponding character must be looked for ; religion, although not specially recognized by the State, being quite as fashionable in America as in England, and hence, in these quarters of the chief cities, we find costly churches of nearly every denomination alternating with lines of stately mansions, and as different in their character and cost from the simple wooden-spired boxes to be found in the villages above-mentioned as can well be conceived. In the poorer quarters of the cities the churches are of corresponding character with the houses around, and may be shortly described as being nearly all of what is known as the "Little Bethel" type amongst ourselves.

The unsettled habits of so many of the American people, and the great expense of housekeeping, causing a large and respectable section of the community to reside in hotels, have developed the latter so as to rank amongst the "great institutions of the country," and as examples of architecture they will require special notice.

The vast commercial relations of the great cities have also required that warehouses and shops, or "stores," as they are called, should assume enormous dimensions, and they are more often than with us highly decorative and palatial in their appointments. Banks and insurance offices, also the offices of

the numerous journals, form splendid subjects for architectural treatment, and are commonly carried out in a liberal spirit.

The post-offices, custom-houses, and law courts have nearly all recently undergone a process of reconstruction on a much grander scale than before, chiefly by the United States Government, and, if we except the miserable pittances paid to the architects, no expense seems to be spared to render them worthy of a great nation. The telegraph offices, albeit still in the hands of private companies, have also recently been taken in hand, and some noble buildings are in progress for these purposes. The railway stations, or "depots," as they are called, are rather behind in the race, being as yet generally temporary wooden sheds, and but one really colossal terminus worthy of comparison with those of Europe, has as yet been erected in New York.

The town or city halls, and the State Capitols, in which the legislatures of the various States hold their meetings, have nearly all been found too small and old-fashioned for modern ideas, and some very noble and magnificent new buildings are either in progress or projected for these purposes.

There are large and handsome theatres and opera houses to be found in every great city, which, from their occupying excellent and commanding sites, and the general spaciousness and elegance of their appointments contrast most favorably with ours. The same may be said of the music and lecture halls, which especially abound in Boston and New York.

Public museums and picture galleries are as yet in their infancy, and can scarcely be expected to rival those of Europe for many years to come, but every large city has a respectable public library, the buildings for which are often costly and handsome. There are in New York, Brooklyn and Boston appropriate buildings for the purpose of annual art exhibitions.

Charitable institutions, such as hospitals and asylums, appear to be as well sustained and appointed as any in the world, and some of the buildings for these purposes are very extensive and magnificent. In a country which has set so good an example to our own on the subject of education, it is only to be expected that schools and colleges would abound. Of these buildings, the public schools, commonly erected by the city or state authorities, though often spacious and well appointed, are rather commonplace building than architecture. The colleges as yet seem to suffer from the want of adequate funds. The two well-known universities, Harvard and Yale, have no state endowments, and are dependent on private munificence. Hence, venerable as they are, they have as yet little to show that can be called architecture, and that little is of a very poor class. Trinity College, Hartford, Connecticut, has recently sent over to Mr. Burges for designs for a new college on an immense scale, which have been illustrated in some of the English journals, and the first instalment of which, I understand, is about being contracted for. One of the latest founded universities, Cornell, in the State of New York, has, however, shown its appreciation of our art by the appointment of a professor of architecture (though, singularly enough, a clergyman has been selected for the post), and I believe similar professorships are in contemplation at Harvard and Yale. There is in Boston an excellent scientific school, the Massachusetts Institute of Technology, which has a professorship of architecture attached, to which, however, an able practising member of the profession, Mr. W. R. Ware, has been appointed. I hope these may be hints to the board of our honored University of Dublin to follow the same example, which has also been set by Oxford, Cambridge, and London.

The public cemeteries compare very favorably with ours, not alone in the sites they occupy, but also in regard to the order in which they are maintained and the substantial character of the monuments, in which granite and marble are profusely employed. Notwithstanding the costliness of these, and the excellence of the materials and workmanship to be seen in them, they more often display ignorance and bad taste in design than otherwise, for the very simple reason that the American public has not yet generally learned the propriety of employing architects upon them, but

orders them directly from stone or marble masons.

In materials for building, the United States appear to be particularly favored. Granite of varied color, admirable texture, and almost unlimited dimensions abounds, and is extensively used in public buildings, for which the largest columns can be had in one piece, and some varieties admit of being polished quite equal to the granite of Aberdeen. It is also used for paving the side walks, in which it is not uncommon to see slabs 15 feet by 8 laid down, giving the whole width required without a joint. White marble exists in great profusion near New York and elsewhere, and is largely used, so much indeed as to become nearly as common as bath or Portland stone in England. It is easily worked, and gives a beautiful surface without being polished, of which operation, however, it is also susceptible. The sandstone in general use is the well-known "brown stone," raised in the states of New Jersey and Connecticut, and extensively employed in the house fronts of New York, for which it is well adapted, its rich warm tints producing a very pleasing effect. There are also lighter colored sandstones used, from Ohio and Nova Scotia. I do not remember seeing any specimens of oolitic stone, such as Portland or Bath, but it is no great loss to be without a class of material which, however easy to work, is equally facile at disintegration. Red bricks are made, especially in Philadelphia, much superior to any I have seen in Europe, and white or cream-colored, in some of the western states. Cement is rarely used as an external coating, the species of architecture in which it would be employed at home being commonly rendered either in stamped zinc or cast iron, the use of which, in the fronts of buildings, is very extensive, and, as characteristic of the country, deserves special notice.

In woods the United States are rich. The several varieties of American pine we are accustomed to here are, of course, much used there also, but in addition walnut, butter-nut, chestnut, ash, oak and other hard woods abound, and are nearly the same price as pine, the only difference of cost being in the working, which again is counter-balanced by the saving in painting. Hence, these woods are extensively used, and give a fine effect to the interiors, being commonly wrought and finished by skillful cabinet-makers (mostly German) with great taste. The ironmongery in general use seems much superior to the corresponding articles used in England, the flaps of the hinges being usually silver-plated or otherwise decorated, so as to produce a very fine effect by contrast with the polished hardwood of the doors.

In plumbing and engineering works applied to buildings, I must say the Americans appear considerably ahead of us. The excellence and finish of the baths, lavatories and other sanitary appliances in the principle houses and hotels, is such as to deserve the highest encomium. The same applies to the warming of buildings by steam and hot water, in which great progress has been made during the last few years, consequent on the severity of the climate in winter, which severity, however, now is scarcely to be felt, so completely are the halls and passages, as well as the principal rooms, kept to an even temperature by such appliances. I think in this particular we have much to learn from the Americans. The use of lifting-rooms, or "elevators," is very general in all the large and lofty hotels, warehouses and blocks of offices, and the perfection of their mechanism exceeds anything I have seen elsewhere, and has the effect of causing the uppermost stories in these buildings to be nearly, if not quite, as valuable in letting as the lower. From all which it will be seen that in materials, workmanship and mechanical appliances the Americans are greatly favored; and such resources, used under the direction of able architects, ought to result in the development of as noble a school of architecture as is to be found in the world. That this result has not yet been attained is unfortunately the case, the cause being, as I believe, to a great extent to be found in the unnatural severance between the artistic and practical, which has hitherto prevailed in American practice. Many of the largest and most important structures, built of the most costly materials, displaying great excellence in workmanship and a high degree of perfection in their mechanical appliances, have been erected

without any architect at all; the proprietor preferring to place himself in the hands of a "practical man" rather than of an artistic genius, who, as he believes (and too often with truth), knows nothing of the value of materials and work, and can do little else than "draw plans." Of course such occurrences are not universal, but there are enough of them to stamp a vulgar and commonplace character on American buildings, and sometimes to get American architects discredit in the eyes of foreigners for what they really had nothing to do with.

I need scarcely say, if we except the Aztec ruins in New Mexico and Arizona, that there is very little architecture of historical interest in the United States; but such as there is, is to be found in the older cities on the eastern seaboard, New York, Boston, Philadelphia, and Baltimore, and recalls the time of Queen Anne and "the days when George was king." It is a very close imitation of English works of the same time. The early years of the Republic, and the commencement of the present century, seem to have given rise to a few respectable old-fashioned practitioners in these cities and in the then newly-founded city of Washington; and the setting in of the Greek mania in Europe was attended by a similar rage for Greek temples in all these cities, and some of the principal United States buildings, including the Treasury and Patent Office are among the results; also the Girard College at Philadelphia. These buildings are, I think, neither any better nor worse than the corresponding efforts of the Greek school at home. The enlargement of the United States Capitol, conducted under the direction of Mr. Thomas U. Walter, one of the leading practitioners of the time, displays a departure from the rigid Greek types so much in vogue, and, despite the execution of the dome in cast iron, must be admitted to be a very noble and appropriate pile. It occupies a commanding site, and the dome stands well up from the rest of the building, and is seen not alone from all parts of the city, but from the country for many miles around, ordinarily under a clear sky. Having seen most of the great domed structures of Europe I am not aware that any of them produces, on the whole, so fine an effect. Since the completion of this great work a long pause took place in the United States Government operations, until the advent of Mr. A. B. Mullett as architect to the Treasury. This architect, during the eight years in which he held office, certainly had opportunities which fall to the lot of few. Some thirty or forty great buildings, costing from £100,000 to £1,000,000 sterling each, and sometimes even exceeding the latter figure, have been planned and either wholly or partially carried out under his direction. Many of these are illustrated in the last report issued from his department, and those I have seen are executed in the most solid and substantial manner, ordinarily of granite in large masses. Their architectural character though peculiar to the department, may be taken as one type of what is certainly developing in the United States as a national style, and which may not inaptly be described as American Renaissance. Other examples of it are the new State Capitol for New York, in course of erection at Albany, under the direction of Mr. Fuller, and the new city buildings at Philadelphia, by Mr. McArthur, to be more particularly noticed furthur on.

The older portions of the cities abovementioned are nearly as irregular an crooked as any European city, but these portions (except in Boston) form but a small part of the area, the rest being comparatively new and laid out in rectangular blocks, which, however convenient for building purposes, are very prosy and tiresome in effect. Where the ground happens to be irregular it produces very disagreeable results, and indeed, as regards convenience, is not without its drawbacks, as it frequently entails the necessity of traversing two sides of a right-angled triangle instead of the third. In New York it is seen to the greatest advantage, the great length of the island as compared with its breadth giving facilities for it, and the distinction between streets and avenues being easily remembered, also the mode of numbering the streets, but in Philadelphia it is particularly tiresome. It was a great pity that in laying out these cities diagonal lines were not occasionally introduced, and that more space was not reserved for squares and parks.

Except Boston, which has a very fine open space in its midst, called "the Common," none of the cities have spaces of this kind worth mentioning within their ordinary limits, although they have all recently added noble parks in their outskirts, the so-called Central Park of New York being one of the finest. One acre of park or square in the centre of a city, however, is worth a dozen in the suburbs, and Englishmen may be thankful to monarchical institutions for giving London such magnificent breathing spaces, running up into the heart of the city, as St. James's and the Green Park. Dublin may also take pride in the fact that there are no such noble squares in any of the American cities as Merrion-square and St. Stephen's-green. The city of Washington is very nobly laid out indeed on the French system, and is not amenable to the complaint of prosiness or inconvenience attaching to the rectangular style of planning, but it has never filled up as expected, and it will doubtless be many years before it assumes a character worthy of its importance. Although the residence of the President, Cabinet and foreign ministers, and pretty lively during the session of Congress, it is not as yet fashionable, and has little of that metropolitan character which, despite State and Governmental arrangements, belongs properly to New York. The latter city is the real centre of wealth, power and influence, and is destined at no distant day to be a formidable rival to Paris and London in architectural grandeur. As it is, the Fifth Avenue rather exceeds in magnificence any one street or avenue in Europe, and it is the centre of a district which is no unworthy rival of the best quarters of the European capitals.

The climate of the United States, and especially of New York, is eminently favorable to architectural effect. The total absence of smoke, and the frequency of bright clear days and brilliant sunshine, have a marvellous effect in making even commonplace architecture lookwell. Just as amid the smoke, fogs, and dust of London or Dublin the works of the greatest masters become grimy and dull, so there the doings even of mediocrity appear always to advantage. It must be consolatory for the Americans to reflect, however, that, while the architecture of their cities is decidely susceptible of improvement, no earthly power can change the climate of the British Islands.

What Sir Gilbert Scott calls the "vernacular" architecture of the American cities was, until within the last twenty years, a reflex of that of the British, the same mouldings and other features appearing in corresponding places. Within that time, however, chiefly from the large influx of German skilled artisans, a vast improvement has taken place, and the details and finish of ordinary house work are now very much superior to those of the same class of buildings at home. The work, as already noted, is generally done by cabinetmakers, and much more elegant forms and spacious proportions are given to doors and other internal woodwork than what are usual with us. Wainscoting is largely used, and the newels and balustrades of stairs are treated in a highly artistic manner, contrasting most favorably with the meagre and skinny forms customary here.

To remark in detail on the various classes of buildings already referred to, it may be observed that the suburban villas are largely built of wood, and in the use of this material for such, the Americans have developed another variety of the national style, which, though often used with extravagance and bad taste, is also often practised with success. Verandahs are found to be an essential feature in all these, and often very prettily treated, and many frame houses are to be seen, especially in the environs of Saratoga and Newport, which form as elegant and attractive residences as could be wished for. The Gothic style is coming into pretty extensive use for this class of house, for which it is well suited. Brick and stone villas are not so frequent, and where indulged in, their architecture conforms more to the English type, whether of Gothic or Italian.

The extensive use of wood in middle and lower class dwellings in the suburbs of the great cities has had a good deal to do with the extent and destructiveness of the fires which have recently desolated some of these cities. At Chicago especially, although the central and business portion of the city was solidly built, there was, and still is to a

great extent, an immense surrounding district composed of small wooden houses, in which when once a fire got head it spread with unusual force to other districts. The rebuilding of the city, although conducted in a more solid manner than before, will be no safeguard against similar disasters so long as this immense surrounding inflammable district remains as it is, or is permitted to be rebuilt of the same materials. However, in many of the cities, stringent municipal regulations have been passed forbidding the erection of frame buildings within certain limits—a wise precaution, as though when standing apart, frame houses are not particularly objectionable on the score of their liability to conflagration ; the case becomes different when a large number are huddled together.

The town houses, of New York and Brooklyn especially, are distiguished by their completeness and elegance. It can hardly be expected that there would be much variety in their external architecture, which is mostly of the American-Italian type, though here and there Elizabethan or Gothic has been tried. The exteriors are, however, generally quiet and gentlemanly in effect, the details of the steps, balustrades, doors and windows being, I think, much superior to ours. The doorways are almost invariably spacious, handsome and inviting, with an external pair of doors disclosing a recessed porch, paved with marble, having handsome glazed doors within. All the wood work being commonly of walnut with ornamental silver-plated hinges and fastenings, the effect is very good. The plans of the houses are different from ours, and are of two kinds, called the "high stoop" and "English basement" respectively, the latter houses being different from anything used in England. The peculiarities of these two plans will be best understood from an inspection of the drawings of each kind. Of course there are many varieties of these two leading types, the "high stoop" being the favorite, and deservedly so, as it admits of considerable expansion. There are some houses of this class on corner lots perfectly sumptuous in all their details and appointments, for the purchase of which sums approaching to £40,000 or £50,000 have been given. The enormous value of land in the fashionable parts of New York renders it almost impossible to get a lot of sufficient size to build a mansion greatly different from the ordinary plan. That of Mr. A. T. Stewart, at the corner of Thirty-Fourth Street and Fifth Avenue is a notable instance, and is built of white marble, and said to have cost, with the site, about two millions of dollars, or £400,000.

These town houses, being some of the most satisfactory buildings to be seen in New York, are, however, rarely the work of architects. I believe originally architects used to be employed on them, and still whenever a very grand one is wanting, an architect is sent for, but they have developed into their present state of completeness chiefly by a tentative process, one builder copying from another this or that improvement, and so on. An English firm, Messrs. Duggin & Crossman, has been distinguished like the Messrs. Cubitt, in London, by the completeness of the houses they have both planned and built. There are in the upper part of New York some very splendid houses from their hands, worthy of the best parts of Belgravia, and costing each, with their sites upwards of £30,000 of our money.

The churches next require to be noticed, and seem quite as numerous as with us, notwithstanding the absence of any State endowment to religion. Although the Roman Catholic and Protestant Episcopal Churches have a large following, the bulk of the religion of the United States is some form of what we are accustomed to call Dissent or Nonconformity, and this has an important influence on the style of the religious edifices, which are called "churches" irrespective of denomination. The older ones to be found in the eastern cities, above referred to, are generally copies of well-known English churches of Wren's time or thereabouts, but more often reproduced in wood than in any other material. The Puritans who colonized the New England States, however they may have hated episcopacy and all its surroundings, seem to have aspired to make the churches they built in the new world as like those of the Episcopal Church at home as possible. Hence in

Boston, Hartford, New Haven and other eastern cities, any one familiar with the London churches can easily count them from their duplicates all round him. Here is St. Clement Danes, there St. Bride's, here St. Martin's-in-the-Fields, there St. Mary-le-Strand, &c. St. Martin's seems to be a prime favorite, and has not only been frequently reproduced in wood, but sometimes in stone also. There is a pretty fair replica of it in the latter material, which has been recently erected for the Unitarians in one of the best quarters of Boston.

There are a few such reproductions to be seen in New York also ; but some of the wealthier Episcopal congregations, following the English fashion, have in later times erected some very substantial and monumental churches, reviving the architectural features of the Perpendicular Gothic period. Trinity Church, New York, by Mr. Upjohn, is the best specimen of this kind ; it is so accurately reproduced from one of the best English models, that with its churchyard and surroundings, it looks like a bit of the old country bodily transported across the ocean. There is another Trinity Church in Brooklyn by Mr. Lafever, which closely resembles some of the large parish churches erected in England some thirty years ago. It has galleries in the aisles between the nave pillars. These two churches, albeit much behind the modern efforts of the Gothic Revival in England, are superior to most of the churches of late date built in the United States. A few of these latter, built for the Episcopal communion by well-known New York architects, show some advance as regards detail and finish, but none of them seem to have been erected under such favorable circumstances as the two above mentioned. The basilican plan with Lombardic details has been adopted in one instance with marked success in the Church of St. Bartholomew, New York, by Messrs. Renwick & Sandes.

The Roman Catholic community has also erected some very respectable churches, and the cathedral for that denomination, now in progress on Fifth Avenue, from the designs of the last-named architects, promises to be as fine as any modern European church of the same class. It is being built of white marble, in the Geometric or Decorated style, and the works are being executed in the most thoroughly sound and substantial manner.

The churches built for the Episcopal and Roman Catholic communions are, as might be expected, no way different in plan or arrangement from those erected for the same worship in England ; but of late years the striving after novelty in the style has led the architects of some of the new and fashionable Episcopal churches to indulge in heights and depths of sensational or "acrobatic" Gothic that are enough to make the hair of some of our Gothic revivalists stand on end. When the architect is done his work, a mediæval decorator is called in, under whose direction the roof timbers, walls and all other available spaces are set ablaze with color and gilding. Nor are the other or non-Episcopal denominations much disposed to remain behind in striving after architectural effect. Although from the simplicity of their worship, and the importance attached by them to preaching, the plans and arrangements have to be assimilated to those of lecture or music halls, still there is a strong disposition to have (externally, at any rate) naves, aisles, transepts, and a tower or spire. Indeed in some instances this disposition has been so strong as to result in the erection of buildings for Presbyterian worship quite as much in accordance with ecclesiastical precedent as any of those erected by the Episcopalians. There is a very elegant Presbyterian Church of this class in Philadelphia, by Mr. Sims, one of the best pieces of modern Gothic to be seen in that city ; and a perfectly sumptuous Dutch Reformed Church on Fifth Avenue, New York, by Mr. Wheeler Smith, which, with some extravagances, displays a good deal of taste and knowledge of Gothic detail, and is executed in the best possible manner.

In general, however, the difficulty of reconciling the conditions referred to has led the architects into all manner of devices and disguises, such as rounding off the angles by studded partitions inside, so that the internal plan and section are often circular or elliptical, while all the external forms are square. About the most notable examples of this kind of treatment are the new church on Fifth

Avenue, New York, for the congregation of the Rev. John Hall (formerly of Dublin) by Mr. Carl Pfeiffer, and the new Church of the Holy Trinity, also in New York, by Mr. Eidlitz. Some of the results achieved in the same manner are positively fearful to the unsophisticated European critic. The problem of providing a spacious auditorium, while maintaining a dignified ecclesiastical character, is one which remains yet to be solved at this side also, but the inducements to attempt its solution are much stronger in America than here. For, as already observed, the bulk of the community there is attached to forms of worship which requires buildings primarily contrived for hearing and seeing, and the sums which are devoted to their erection are such as ought to be sufficient to carry them out in a suitable and dignified manner.

Amongst the forms lately introduced for the plans of such churches is the semicircular or that of the Greek theatre, which has been found very successful for hearing and seeing. Such a plan would admit of very effective treatment in the Classic style, but as that has gone out of fashion, attempts have been made to adapt the Gothic style to it, especially at the Rev. Mr. Talmage's tabernacle at Brooklyn, but the result has been anything but a success. Those who remember seeing Mr. Burges's design for a senate house to one of the universities, will be disposed to admit that even in his hands a semicircular plan proved very intractable with Gothic details. Other and more fearful results have been attained by another architect, who has received somewhat of a reputation, by disguising semicircular plans with heaps of towers, minarettes, colonnades, &c., carried out in galvanized iron, as in the Rev. Mr. Hepworth's new tabernacle in New York.

The internal fittings, being nearly always of hardwood, are much superior to the general run of those in our churches, and a much greater degree of attention is bestowed to the comfort of the congregation than with us. The vestibules, passages and pews are usnally carpeted, and the warming and ventilation carefully attended to. On the whole, it must be admitted that the American churches are much more comfortable to worship in than our own.

The American hotels form, as observed, a notable "institution" of the country. Built not alone for strangers, but for residents, who board in them to an extent unknown with us, they are usually of colossal dimensions, and should form noble subjects for architectural treatment, though it is to be regretted that they are just as often built without architects as with them. In the large cities the ground floors fronting the streets are ordinarily occupied by shops (or "stores," as they are called), to each of which there is an entrance from the central hall of the hotel, so as to enable the guests to do their shopping without going into the street. The entrance-halls and corridors are unusually spacious, and form a sort of general lounge or exchange, as much frequented by outsiders as by those who may be staying in the house. Off these are billiard, smoking, reading and writing rooms, a telegraph and post office, and office for the sale of theatre and railway tickets, a gorgeous bar for the sale of liquors, newspaper, book and cigar stands ; a barber's shop is an invariable adjunct, with bath-rooms and lavatories attached. To secure privacy to the fair sex, a separate entrance for ladies is almost always provided, through which they can reach the most private parts of the house without passing through the Babel of loungers and smokers which ordinarily prevails in the main hall. These private rooms, including dining and drawing rooms, are laid out on a most spacious scale, as also are the various suites of private rooms, to which, when on the upper story, access is commonly had by means of elegantly-furnished and appointed "elevators" or lifting rooms. The hotels at the watering places and in the country differ in having spacious verandahs or colonnades surrounding them, and generally a magnificient ball or assembly room is attached. It is clear that, conceived on this scale, no finer architectural subjects could be wished for; and when we note that white marble and other costly materials are extensively used in them, the principle will be still more manifest. The new and colossal ones at Chicago are certainly very grandiose in effect, and

the best architectural talent of the place has been brought to bear on them; but there are others in which such has been the case, and, however spacious and convenient, they are commonly huge masses of ugly building rather than architecture.

The last large new hotel on Fifth Avenue, New York, was planned as well as built by an enterpising "boss" builder (a native of this country), it being the practice of such men sometimes to profess that they "keep an architect" for the purpose, much as Moses and Son used to keep a poet. The building is a large ungainly pile of red bricks about nine or ten stories in height, but has been sumptuously fitted up inside by some of the able German cabinetmakers or upholsterers already referred to, displaying all "the wealth of Ormus or of Ind," and no doubt producing its full effect upon "kings barbaric," such as Kalakua of the Sandwich Islands, who, as well as the late Lord Mayor of Dublin, were amongst the recent distinguished guests.

The warehouses and shops (or "stores, as they are called) in such a commercial community, also assume colossal proportions. In them more particularly the use of cast iron is general, not alone for internal columns, as with us, but also for all external architectural features. Facades eight and ten stories high are executed in it, and with an excellence of finish and accuracy of detail that is seldom seen at this side. There are several large foundries called "Architectural Iron Works," in which the stock of models is very extensive, comprising all the best examples of the Greek and Roman orders to almost any diameter. The facility with which these can be put together to form showy fronts, has had a very decided influence on the street architecture, which exhibits a great tendency to run into columns, and the repetition of the same details through nine or ten stories is very common. Indeed so prevalent have these characteristics become, that even where cast-iron is not used, the influence of the cast-iron school in this direction is felt. This is noticeable in some of the Great United States' buildings already referred to, which, although built of cut granite, exhibit one order with little variation used through all the stories. This must be looked on as a decided element in what may be called the "American Renaissance" style. Other characteristics of it are the extensive adoption of the mansard or pavilion roof, which is not so much a constructive necessity as a matter of taste.

The ordinary covering of American buildings is tin in plates about a foot square soldered together, laid on boarding with very little inclination. In order to make the roof show, at least in front, however, a steep-pitched or curved roof covered with slate is commonly used towards the street. Recent municipal regulations have required that the rafters, &c., of these should be of iron, and cast-iron crestings and ridges of gorgeous patterns are used upon them.

In the application of cast-iron both to the constructive and decorative portions of their buildings, the Americans have displayed much skill and taste, and at first sight it would seem that the extensive use of this material would be an effectual safeguard against fire. This, however, is seldom the case, as although the facades may be of iron, as above described, the floors fitting into them are of wood, and, from its cheapness, the latter material is used much more freely than with us. Of late years brick arched floors on rolled iron joists have become more general, but still wooden floors and staircases are used in most instances, where stone would be employed with us.

Some of the most important warehouses are not built of cast iron, but of marble, forming very imposing piles of building; and in some of the more recent cast-iron ones, where architects have been employed, praise-worthy attempts have been made to adopt architectural forms, which should not be derived from or suggestive of stone, and in some instances with a fair amount of success.

The banks, insurance and newspaper offices may be placed together as forming another class of buildings on which enormous sums are expended, and architects nearly always employed. Some of these are very magnificent, usually of brick, stone or marble, and quite as sumptuous in their internal appointments as the London buildings for the

same purposes, except that the newspaper offices in the old country do not deserve to be mentioned in the comparison, being, as we know, downright mean and contemptible. The Equitable Life Insurance office, by Mr. Gilman; the New York, by Mr. Thomas; also the Connecticut Mutual and Charter Oak, at Hartford, by Messrs. Bryant & Rogers, will compare favorably with any similar buildings in England or Ireland; but we have no newspaper offices worthy of mention besides those of the *Staats Zeitung* and *Tribune* in New York, the works of Messrs. Fernbach & Hunt respectively.

The architecture of the last-named building is different from anything hitherto described, it being of red brick with granite intermixed, and of a style peculiar to the architect, Mr. R. M. Hunt, whose works are distinguished by great originality and beauty of detail. Their characteristics are difficult to describe, and they will be best understood from inspection of the drawings or photographs of his buildings. Modern French, Gothic and Greek elements are to be found in nearly all his designs, and yet most skilfully and tastefully combined, so that his detail is almost always worthy of close examination and study.

The most important of the telegraph companies, the Western Union, has recently completed a magnificent building for its head office in Broadway, New York, ten or twelve stories in height, of granite or red brick, from the designs of Mr. G. B. Post, the details of which are remarkably elegant, the execution throughout solid and substantial, and altogether the effect very fine as a specimen of a more advanced type of American Renaissance than what has been previously alluded to.

The city hall of New York belongs almost to a past age in the brief architectural history of the country, but it is solidly built of white marble, and really looks what it is, an uncommon point of excellence, where the uniformity of the prevalent style makes it often difficult to distinguish the purpose of a building from its external appearance. That of Boston is newer, of French Renaissance type; but Philadelphia is outdoing all rivals in the erection of the magnificent town hall already referred to, a full set of photographs of which, kindly presented to me by the architect, Mr. W. McArthur, lies here for inspection. The contract for the marble work alone of this great building reaches almost one million pounds.

The United States law courts are commonly held in the same buildings as are used for the post offices, which are, as already described, under the direction of the United States' Treasury; but besides these there are local courts in each city, which as yet are but in few instances worthy of their importance. The city of New York certainly has paid pretty dearly for the unfinished building in which its courts are held, the contracts for which were manipulated by the infamous Tweed Ring so as to make it considerably more than the Houses of Parliament in London. It is a respectable piece of Roman architecture in white marble, and is to have a dome when completed. The court rooms are nearly all square, with few and simple fittings, and are considerably more spacious and lightsome than the corresponding rooms with us.

The state capitols form perhaps the most ambitious class of public buildings, and several new ones on a grand scale are either in progress or projected. That for the State of New York, at Albany (already referred to), by Mr. Fuller, has been illustrated in more than one English journal, and promises to be one of the greatest buildings in the world. It is being carried out in the most solid and substantial manner, and will probably cost almost four millions of pounds. Several others on a smaller scale have been erected in various parts of the Union, generally in the Classic style, and nearly always with domes, suggestive, no doubt, of a family resemblance to the great U. S. capitol at Washington. The State of Connecticut, however, has shown a decided preference for Gothic, and in a recent competition the designs of Mr. Upjohn in that style were selected, and the building is now in course of erection in a thoroughly substantial manner, in granite and white marble, under the direction of Mr. Jas. A. Brown. The contractor, Mr. J. G. Batterson, of Hartford, is distinguished as the proprietor of extensive granite

and marble works, and has contributed largely to the development of the geological resources of the country. The design is noticeable as an attempt to adapt Gothic details to a dome, a feature that some of our leading Gothicists have long desired to reconcile with their favorite style. The cost of this building will probably be about half a million pounds, and another of nearly the same cost is in contemplation for the State of Indiana at Indianapolis.

It will perhaps illustrate the rapidity with which progress is made in the United States when I refer to the complaint* of the late Charles Dickens, that at the time of his first visit no respectable theatre existed in New York, and contrast it with the existing state of things in which that city possesses three or four of first-class dimensions (as large as Covent Garden or La Scala), and a host of minor ones, nearly all of which have greatly the advantage over the London and Dublin theatres in not being huddled away into disreputable quarters, but occupying noble and commodious sites. They are also in general constructed in a more spacious and substantial manner, with wide doorways and passages, and are handsomely furnished and carpeted. The planning is not usually so intricate or scientific, or the decoration so artistic, as in the English or French theatres, but the conditions to be observed are simpler, and the interior effects of some—particularly the academies of music of New York and Philadelphia—are very fine. The external architecture of these two great theatres is simple, being chiefly of brick, but nevertheless is fairly appropriate and expressive; whereas two other theatres, Booth's and the Grand Opera House—the exteriors of which have been executed at enormous expense in granite and marble,—though showing handsome facades, do not appear at all like what they are, and might pass just as well for hotels or banks. In music halls, Boston decidedly carries the palm, having one of the finest I have ever seen, with an organ of stupendous dimensions and power.

* A similar complaint of more recent date is made by Mr. Anthony Trollope against the railway traveling, which, since the introduction of the Pullman drawing-room and sleeping cars, has become much more comfortable and luxurious in the United States than in the British Isles.

The buildings erected for the academies of fine arts, both in New York and Brooklyn, are some of the most favorable specimens of secular Gothic to be seen in these cities, and are the works of Messrs. P. B. Wright and J. C. Cady respectively. These societies, wholly voluntary and self-supporting, have established annual exhibitions of the works of living artists, which are well supplied and attended, and will no doubt grow in importance from year to year. Buildings for State museums, both of the fine arts and natural history, have been commenced in the magnificent Central Park of New York, to receive collections, including that of the Cyprus antiquities, recently purchased by General Cesnola, which are in process of formation. The designs for these buildings are in the hands of an able architect, Mr. Jacob Wray Mould. A very effective building for a public library, rather in the modern French style, is in progress near Central Park from the designs of Mr. Hunt, who was also the architect of the Presbyterian hospital in the same direction, one of the best pieces of secular Gothic to be seen in America.

It is not possible in the limits prescribed for such a paper as this to do more than glance at some of the most prominent of each class of buildings, and I will now proceed to a few remarks on the condition of the profession. It is not by any means as flourishing as the large amount of building doing in the country would lead one to expect. Nevertheless, there are in each large city a number of very successful practitioners, and there is no reason to doubt but that the number will increase according as the American public begins better to understand and appreciate architects and their art. The architects themselves have much to do to diffuse a wider knowledge on the subject, and also, as I have endeavored to show in my previous paper, much to improve in the style of their practice. At present—no matter how lavishly money may be expended in brick, granite, marble, wood or iron, amounting, as will be seen, to four or five times the sums expended on similar buildings in the old country—the American public seems to have little confidence in its architects, and seems disposed to employ and re-

munerate them only on the most limited scale. What stronger instance of this could we have than that of the architect to the United States' Treasury, who, while planning buildings that cost from ten to twenty millions of dollars annually, receives but 4,000 dollars a year himself, or about three times the pay of a bricklayer in the same country? The gentleman already referred to—who filled that office for eight years, and displayed no ordinary ability in the conduct of the vast works entrusted to him—has, it is said in the papers, retired comparatively a poor man, nor has there been any allusion to a pension. Architects in private practice can do much better, of course; but the disposition is very much, as in the case mentioned, to do without them if possible, and even when they are employed, to limit their functions to the supply of the necessary drawings—the superintendence, adjustment of accounts, &c., being placed in other hands. The American public cannot, however, be blamed for this, when the profession itself neglects these two important branches of its duty. It has been credibly stated of a well-known New York architect that, when asked by his client how much the brickwork of a building would cost, remarked that "he had not the least idea, as he really did not know how bricks were sold, whether by the pound or otherwise." No wonder if after this, clients conclude that architects are only fit for drawing pretty pictures, and feel disposed to get rid of the architect once the drawings are prepared, or else place the next monster hotel or warehouse wholly in the hands of some so-called "practical man," as in the cases already alluded to.

The neglect of the financial element in their practice by American architects recently called down on the profession a severe rebuke from the late Governor of the State of New York, who, in his message to the Legislature, drew attention to the fact that State buildings had cost on the average about four times the amount of the architects' estimates. In consequence of this alarming discrepancy he recommended that in future the architects should only be employed to furnish the drawings, and that when once these were obtained a builder should be employed to superintend the work, including the adjustments of estimates, contracts and accounts. This is simply carrying out by the State the same principle which so generally prevails in private practice, and considering architects as mere draughtsmen, unfit to be trusted with anything beyond the limits of their drawing boards. In fact the very word is misunderstood, and whenever a member of the craft wishes to let the public know that he is anything more than a draughtsman, he has to advertise himself as "architect and superintendent of works," as if the former did not necessarily imply the latter.

Among the most obvious wants in America is a weekly journal devoted to the interests of the architectural and building public. In a country where journalism in all other departments is so fully worked, there seems every reason to anticipate success for one such. At present the English building journals circulate largely, but they can neither give local news nor be desirable media for trade advertisements. There is a monthly journal called the *American Builder*, very good of its class, but once a month is not often enough either for news or advertisements.

The most respectable members of the profession in the United States have, during some years past, organized an American Institute of Architects, allied in its objects to those of this Institute, and the Royal Institute of British architects, and deserving of the good will and sympathy of all similar societies, and which, it is to be hoped, will tend, sooner or later, to bring the profession to occupy a higher place in public estimation. It is organized on an admirable plan, by which undue preponderance is not given to any one city, but chapters formed in each, holding meetings and attending to local affairs, all meeting annually in a general convention held in one or other of the chief cities by rotation. This institute owes no small degree of its utility to the secretaries, Messrs. A. J. Bloor and Carl Pfeiffer, to whom, and to the Secretary for Foreign Correspondence, Mr. H. A. Sims, the author of the present paper is indebted for many courtesies. He would be glad

to see the British and Irish Institutes maintain the most friendly relations with so worthy a body, and that all may unite in the sanguine hope that whatever of excellence there is to be found in the past or present of American architecture, is as nothing to what will be realized in its future.

THE IMPROVEMENT OF THE MISSISSIPPI—REPORT OF THE COMMISSION OF ENGINEERS.

From the "New Orleans Bulletin."

The Board of Engineers convened at Port Eads, La., on the 17th of November, and, after examination of the work and subsequent consultation, adopted on the 20th the following general report, and ordered it to be entered into the minutes of the proceedings:

November 20, 1875.

After having devoted three days to examining the works in progress and in conference with Mr. Eads and his Engineers, the Commission presents the following general summary of its views:

Upon personal examination of the locality and observation of the work which has been performed, the South Pass of the Mississippi is found by the Commission to more than fulfill the expectation of its members in regard to its fitness for furnishing an "open mouth" of ample depth for the largest class of sea-going vessels to the Mississippi River by means of jetties.

In making this statement, reference must be had to the fact that two of the members have never before examined the locality with a view to this particular question, one indeed having never before visited the spot. Of course on all points concerning difficulties of execution of the works recommended, they had had no actual local experimental results, while on the other hand, opinions were rife among many that the local peculiarities of the soil, such as its extreme softness, its eruptive "mud lumps," etc., would effectually thwart efforts to lay upon it substantial and permanent engineering construction.

The members of the Commission had, indeed, satisfied themselves that such opinions were unfounded; but it is satisfactory to be able to state positively, after four months of actual operations, that the work of pile driving, extending from the east land's end to twenty-six feet depth beyond the bar crest, along a line two and a quarter miles in length, covering nearly the whole length of the eastern jetty, and an examination of the texture of the bar and of the shoals on which the works are to rest, furnish the most satisfactory evidence of a bottom material not only adequate to bear all the necessary works, but even to suggest that but for motives of economy (quarries being far distant) the jetties, as at the Sulina, mouth of the Danube, might be made wholly of stone. The Commission, therefore, unhesitatingly announces that the supposed or attributed engineering difficulties of construction of engineering works at the South Pass of the Mississippi as depending on peculiarities of the Mississippi delta are illusory.

In fact the execution of the works is far less difficult than that of several recent successful works of the kind on European shores, known to and examined by the members of the Commission. This facility of execution arises, in a measure, from the fact that the broad, lateral shoals, almost bare at low water, which extend seaward from the land's ends, marginal to the channel, form very good protection to the proposed works and almost reduce them to the grade of mere river works until the outer edge of the bar is reached. The deep water portions, outside the bar of the proposed jetties, are comparatively short. While these portions must have the dimensions and strength of exposed sea works they offer no difficulty not common to other similarly exposed works now existing.

It would seem proper in this connection to say a few words as to the South

Pass itself, in reference to its capabilities to furnish an open mouth to the main stream, and thus form an adequate connection between the sea and the thirty thousand miles of inland navigation, which ramify from the river.

The South Pass is the middle one of three great Passes, into which the river, after having for many hundred miles rolled in a single channel, divides a few miles before it finally discharges its waters into the Gulf of Mexico.

It is but twelve miles long, being the shortest of the Passes. From its point of division, it carries its waters in a channel everywhere five fathoms or more in depth, with a straightness of course and a uniformity of section and depth such as almost to suggest to the voyager that he is navigating a canal of unparalleled dimensions, of a width averaging 700 ft., sufficient for the convenient transit of the largest sea-going ships and of the congeries of vessels which constitute a tow for the powerful tugboats in use. No sharp bend, no shoal, no reef embarrasses its navigation.

At the origin—the head of the Passes—a shoal indeed lies in advance of its entrance. This shoal has, however, a natural depth equal to that over the bar of the Southwest Pass, and the Commission anticipates no serious difficulty in effecting over it the required depth. From this point the adequacy of depth continues unbroken for ten miles till the seaward extremities of the land margins (the natural jetties which thus far maintain it) are reached. Here, released from confinement, the current diffuses itself; the depth diminishes until at two miles further (about) the bar, having but seven feet depth, is reached ; beyond which, seaward, depths of 6, 12, 24 and more fathoms are found in quick succession. The specific engineering work which the Government of the United States has committed to Mr. Eads is by the well-known method of Jetties, or otherwise called "parallel piers," to supply artificially throughout this two miles from the land's ends to the outer slope of the bar the confining barriers which shall prolong to the sea the uniformity of section and depth which the natural barriers for the preceding ten miles have secured.

This is not the place to discuss the abstract merits of a well-known method which has elsewhere in reference to its application here, been thoroughly discussed and disposed of, and in which the individual members of the Commission have had each one his own part to take. What has been said in former paragraphs suffices to exhibit the strengthened confidence with which personal examinations of the spot and of the works now in progress has imbued the members of the Commission.

The Commission consider the present an opportune moment to record its opinion. First, that the Physical characteristics of the Delta and Bars of the Mississippi and Danube, are similar in many important respects. And secondly, that owing to the greater sea depth immediately beyond the crest of its bar, to the existence of tide-water, to the apparent greater abrading forces along the Coast, and to the extreme fineness of the sand, of which the Bar is composed, the mouth of the South Pass of the Mississippi is *more* susceptible of successful improvement, notwithstanding the greater turbidity of its fluvial current, than was the Sulina mouth of the Danube, when in 1858, the construction of parallel piers was commenced, which secured to the navigation of that river a depth of 17½ feet in 1861, and of 20½ feet at the present time, or five feet more than the works were originally designed to obtain; and this at the mouth of a river-arm discharging less than one-third of the volume of water discharged by the South Pass.

We now turn to the works actually at this time executed by the grantee, Mr. James B. Eads, under the act of Congress authorizing him to improve the South Pass of the Mississippi River, and we find that they have been laid out and thus far carried on substantially in accordance with the plans submitted to and approved by this Commission at the time of their session in September last.

Considering that only the short period of five months has elapsed since the beginning of operations at the South Pass, we are struck with the amount of work which has been accomplished ; and although much that has been done is provisional, to be supplemented by other work, it is all necessary and conducive

to the end in view, which is permanently to confine the flow within the space of one thousand feet between the crests of the jetties.

We find from the records of the pile driving, and from the manner in which the piles have thus far withstood the action of the waves and currents, that the material of the bar is even more solid than we had ventured to anticipate it would be, as we have already remarked. We do not entertain any doubt as to the efficiency and permanency of the jetties when they shall have been completed upon the location and plans heretofore approved by this Commission. If the arrangements made by the contractors, Messrs. James Andrews & Co., for the early delivery of additional large quantities of stone for weighting the mattresses, and for the protection of the jetties against the action of the sea, are successfully executed, we see no reason for doubting the realization of definite and permanent good results at an early date. It is hardly within our province, if it were even in our power, to offer any specific opinion respecting the period when a given depth across the bar may be reliably calculated upon, since so much necessarily depends upon the character of the season, the stage of water in the river, and the vigor with which the work is prosecuted ; but judging from the amount and character of the work already accomplished in advance of the date at which Congress required it to begin, we are very favorably impressed, believing that there is a prospect of early and complete success.

The lines of the jetties are now distinctly marked out by the rows of piles extending seaward on the east side beyond the crest of the bar into twenty-six feet of water, and on the west side to about twenty feet depth, indicating the extent and shape of the new entrance.

While it would have been unreasonable to have anticipated at this early period in the progress of this important undertaking even as much as has already been effected, we desire to be careful lest we should ourselves undervalue or cause others to view lightly the difficulties which yet remain to be overcome before the final grand result shall have been attained.

Care should be exercised to strengthen the works already commenced, in order to enable them to resist the gales of winter—and too much haste to call in the river forces, for the execution of deepening, must be avoided. It is much safer while the foundations of the jetties are insufficiently protected by stone, to allow the present escape of water by lateral avenues.

From what has already been said, it will have been clearly enough seen that the Commission did not expect at this early stage in the progress of the work that much scouring effects would have been produced. Such results cannot be expected to exhibit themselves in a very marked manner, until, by the closure of the opening, 600 feet in length at the head of the west jetty, and by the raising of both the parallel piers to the water surface throughout some considerable length, the water shall be confined to its destined channel. From the eastern land's end to near the head of the west jetty, the eastern jetty is now for the most part thus raised, while the west bank itself imperfectly fulfills the function of its parallel pier. Throughout this length—say for 4400 feet—a marked scouring effect has taken place.

At this season of the year, when the river is low, the scouring action of the current is reduced to its minimum. This, while it is the least favorable for the exhibition of results from the jetty works thus far executed, is the most favorable to their safe and rapid construction. It is quite undesirable that any considerable deepening of the bar should occur berore the spring shall find the works in a condition to resist and turn to useful account the flood that may then be expected.

On motion :

Resolved, That a copy of the minutes and of the foregoing resume be furnished to Mr. Eads by the Secretary. Whereupon the Commission adjourned *sine die.*

J. G. Barnard, President.
Charles A. Hartley,
W. Milnor Roberts,
Henry Mitchell,
H. D. Whitcomb.

A true copy from the minutes.
H. D. Whitcomb, Secretary.

TERRA COTTA AND STONE WARE AS APPLIED TO ARCHITECTURE.*

By. Mr. JAMES DOULTON.

From "The Architect."

Of all materials that of clay is perhaps the most useful, and in the present age there is scarcely any trade which is not more or less dependent upon it for help of some sort in its manufactures; but this is pre-eminently so in building, where it becomes not a mere help, but an absolute necessity.

Every class of pottery may be comprised under the term terra cotta, or burnt earth; but there are so many kinds of clay, and such a variety of ways of manipulation, that they need some distinguishing appellations, and hence the terms china, porcelain, earthenware, stoneware, terra cotta, &c., each pointing to a special class of ware. But whatever the nature of the manufacture, the first step is common to all, that of the clay being well kneaded. This is as it were the foundation, which if neglected the superstructure will be useless.

The clay for both terra cotta and stoneware may be the same, but it is the treatment that changes the character. In the one instance we have a comparatively imperishable material, naturally unglazed, but which may be glazed at will; while in the other the much more intense heat shrinks the clay to a greater density, and by the addition of salt it is covered with a vitreous glaze, and is impervious not only against atmospheric agencies, but against the strongest acids. Terra cotta, up to the present time, is the only one of these that has been used in architecture, and of this we will treat first.

The kneading of the clay, of which I have already spoken as the first necessary, was originally trodden by men, but now it is pugged through mills; though there are still factories where the primitive system is in use. The clay itself being mixed with other necessary ingredients according to its nature, in a dry state is lifted into the pug mills, where water is added, and by the regular adjustment of its supply the same shrinkage may always be depended upon; the shrinkage being caused by the evaporation of the water used in the manufacture, consequently the less water the less shrinkage. In the course of pugging there is a chance of air getting confined in portions of the clay, which if allowed to remain would be sure to cause destruction while passing through the kiln. To avoid this the clay must be wedged, which is done by continually cutting a lump with wire and striking the pieces violently against each other. The clay being thus prepared, is pressed into the mould, which has been previously made from the model in the usual way. These moulds are of plaster. The process of filling them needs care, for if carelessly done there is a liability of air being incorporated in the body, and the same results as already mentioned would of course follow.

In pressing the clay into the moulds, it should be as nearly as possible even in thickness throughout. Again, the presser introduces into his work, when it consists of large pieces, a series of strutts; this keeps it well together when in a wet state, and at the same time adds considerably to its strength when burnt. The strength may also be increased by thickening the walls. This of course applies to all repetitive work; but when one or even two of a pattern are required, the artist's original production may be burnt.

Of course there are risks in this, from the many accidents to which it is liable in its various stages, and if a piece thus made and burnt be destroyed, the skilled labor or the art work has to be done again; but in properly conducted factories these risks are reduced to a minimum. Many carefully modeled works have been destroyed in the burning from the want of knowledge in this department. In statues, especially, there are so many thicknesses, that without great care and this knowledge distortion is

* From a paper read before the Liverpool Architectural and Archæological Society.

certain. I have known figures made that were solid throughout, and to ensure success in burning had to be dismembered, the clay thinned, and then all reinstated. The most critical time for terra cotta is after it has left the finisher's hands and is drying; this process must have time, it being essential that the moisture should be evaporated as evenly as possible. Should it dry in one place before another it is sure to warp and crack, and no after labor bestowed upon it will ever restore it. Thus it will be seen how many difficulties have to be overcome in the manufacture, and I have thought it necessary to dwell on them in order that the peculiarities of the material may be the better understood, and disappointment avoided by architects desirous of using it.

An eminent architect of the present day calls terra cotta "the highest development of brick," and rightly so, for though it is oftentimes effectively used in stone buildings, its legitimate place seems with brickwork. There are a few examples scattered about in our country, but our architects never seem to have made any but the scantiest use of this material. Wedgewood himself strove to overcome this prejudice, but without success.

For abundance of examples we must therefore look to other countries, where its advantages have been understood and made use of, such as Pomerania and other places in Northern Germany, as also Lombardy. These countries form vast plains, where stone is not found, but where clay is more readily obtainable. Stone could only be procured at great cost; clay, the material at hand, accordingly came largely into use, and architects studying its peculiarities designed accordingly.

The advantages in the use of terra cotta are many, and though it has been known for ages past, has been sadly neglected in these latter times. But while it has many advantages, it is but fair to state that it has also disadvantages; and I will endeavor to lay both before you, leaving the matter for your judgment, as being far more competent in such matters than myself.

The first things to be studied appear to me to be durability and strength, and here terra cotta compares most favorably, especially in the former. Its superiority is the more noticeable in the present age, the formation of cities, towns, &c., causing deleterious elements to mingle with the atmosphere.

The increased consumption of coal, together with the subtle and destructive nature of the vapors given out by factories, require that our buildings to be permanent should be composed of as nearly as possible imperishable materials. Stone, it is very certain, does not supply this desideratum. It was only a short time since that I heard of a building in London of Bath stone, just erected, needing renewal in parts almost before the scaffolding was removed. A portion of the cornice and ballustrade from the church at the top of Langham Place, built about fifty years, fell a short time since with almost fatal results, and has been renewed in the old material, and not in terra cotta, on account of the contrast between that and the soot-stained stone. In the gardens of Buckingam Palace are some vases, sharp and sound, while the stone pedestals on which they stand are fast decaying. There are many ornaments in the Palace front of terra cotta which show not the slightest signs of decay, while it has been found necessary to paint the stone to preserve it. There are other stones more durable than Bath, but they are more expensive. Bath stone itself attains considerable age sometimes, but the present state of our Parliament Houses, where, doubtless, every care was used in the choice of the stone, proves how uncertain it is; whereas the selection of good terra cotta is such an easy matter that any ordinary workman need never err therein. In London many instances may be found of the durability of terra cotta and the untrustworthiness of stone; in fact, nothing seems able to withstand the London climate so well as terra cotta. Granite, indeed, is enduring, but its costliness will always prevent its general use. The bronze lions at Trafalgar Square are already showing many weak points: the panels have done so long since. At a mansion in Bedfordshire, far from any town, I saw, a few years ago, terrace after terrace of Bath Stone in a most deplorable condition, the ballusters being worn in some

places to shreds, while the capping and base, were not entirely gone, had become mere shapeless lines. This would show that the smoke of towns and the vapors of factories are not always answerable for such destruction.

The church in Euston Square, London, has a quantity of terra cotta about it, in a good state of preservation ; and, to come nearer home, the figure of Britannia in this city, on the Town Hall, is a specimem of Lambeth manufacture we have no occasion to be ashamed of. Hampton Court Palace possesses some good examples of red ; and in the time of the Tudors were erected many mansions in which terra cotta was used, which remains good to this day. Tracing farther back still, we come to those specimens I have already alluded to in Pomerania, Lombardy, &c., some of which were erected in the tenth, twelfth, thirteenth and fourteenth centuries, while the San Pietro in Ciel d' Oro, at Pavia, is attributed to the early part of the seventh century. But a visit to the British Museum will surely convince the most skeptical. Here may be seen slabs of burnt clay which date not tens, nor hundreds, but thousands of years back, covered with delicate writings, showing as clearly as the first day they left the operators' hands. To these slabs we are indebted for almost all we know of prehistoric times. The wonderful discoveries in the present day by Mr. Smith, whose perseverance has been of late so richly rewarded, is but another instance of what I have asserted.

There is no doubt, however, that a material calling itself terra cotta has been used of such an inferior character as to disintegrate immediately on exposure, and many, knowing only the spurious, have been prejudiced against the genuine. Such terra cotta has been improperly fired, there not having been sufficient heat to produce the chemical change which gives to it its indestructible character. The slightest knowledge of the matter would prevent the use of any but good terra cotta, since such may be readily ascertained. Well burnt, enduring terra cotta should ring under a blow, and when sharply struck with a piece of iron show only a black mark as of a pencil, and at the same time emit a spark. These tests are very simple, and as sure as they are simple. I cannot do better in concluding this part of my subject than quote from the works of the late Sir Charles Lyell, who, in his *Antiquity of Man*, says : "In the vast changes this planet has undergone few things remain to mark the Arts of its earliest inhabitants. Flints, spear heads, arrow heads, fragments of iron, of bronze and of pottery are almost all that remain. Of the latter burnt bricks, jars, vases, the human figures in burnt clay are found in the remains of submerged towns, in the channels of the Nile and in Upper Egypt, in the Mexican buried ruins of America and elsewhere, as the enduring types of civilization of peoples and races, whose names even are not known in the pages of history. Granite disintegrates and crumbles into particles of mica, quartz and felspar, marble soon moulders into dust of carbonate of lime, but hard burnt clay endures for ever in the ancient landmark of mankind."

And now let me state a few statistics respecting the strength of terra cotta, and in this it is quite able to hold its own.

Generally speaking terra cotta pieces may be so formed as to resist any ordinary strain, but when extra strength is needed, it is obtained not only by thickening the walls, but by filling the blocks with concrete formed of hard rubbish and Roman cement In resorting to this plan, care should be taken not to use too much cement, nor any, indeed, of a class liable to swell, as in this case the work may crack from the bursting power within. We once supplied some cornice, and advised the clerk of the works how to act should he fill it, and in this case it was not needed for strength, but only to prevent the chance of water soaking in through imperfect joints and being retained. Many pieces, notwithstanding, were filled with neat Portland, of course with disastrous effect, and I had much difficulty in satisfying those concerned with whom the fault lay.

In the year 1868, Mr. Charles Barry, the architect of one of the finest examples of modern terra cotta (I allude to Dulwich College), directed Mr. Blashfield to undertake a series of tests to ascertain the strength of terra cotta in comparison with other materials.

This was done with the following results:

	Tons.
A 12″ cube of Portland stood a crushing strain of.......... ..	283
The same of Bath................	88
The same of terra cotta.........	442
A good hard stock brick, 9″×4½ ×3″........................	17
A piece of terra cotta, same size, almost solid...................	125

Tests were also made to show the value of filling hollow terra cotta:

	Tons.
A block of hollow work bore a strain equal to the foot square of...........................	22
The same filled..................	45

But these were not crushed until the immense weights of 80 and 163 tons respectively to the square foot were applied.

Weight is another advantage which terra cotta possesses over stone, and which indirectly affects its cost. Being considerably lighter than stone, there is a saving in transport and handling. In stonework carriage is paid on much that is useless. For carved work the rough blocks are lifted into position, and worked off afterwards; the hoisting being troublesome, and not without expense. Terra cotta, on the other hand, is delivered on to the works finished and ready for fixing, and, being hollow, is of course more easily managed, and where filling is required, it is done on the works.

This decrease of weight has likewise another advantage in diminishing that of the superstructure of a building:

	lbs.
Portland stone weighs per ft. cube.	158
Ancaster " " "	140
Bath " " "	140
Terra cotta, solid " " .	100
" hollow " " .	56

In the matter of cost, terra cotta again compares favorably, and this question of price is constantly thrusting itself to the fore, and I am sure must be a great nuisance to architects, compelling them often to give up their well thought out ideas. Many a building has been spoilt, and the architect blamed, on account of enforced reductions for economy's sake. In London the price of terra cotta would be on an average 20 per cent. less than Bath, and about 40 per cent. less than Portland. Much of course depends upon repetition. In all work models and moulds must be prepared, but for large quantities such an item is reduced for each piece to a mere bagatelle. This comparative cost is again influenced by the character of the work. Where this is plain, consisting for instance of mouldings only, it approaches nearer to stone, but where modeling and undercutting is necessary the advantages is much more marked.

The proportions I have quoted may at times be altered by local influences. Stone may be close at hand, while terra cotta is only obtainable from a distance. or *vice versa*.

Thus I have mentioned four of the advantages of terra cotta—durability, strength, lightness and cost. These may be supplemented by the power of obtaining colors. This is done by applying the color to the burnt terra cotta, and subjecting it again to the fire, previously coating the piece operated upon with a glaze, which, becoming incoporated with the body, firmly fixes the color beneath it. The only natural colors of the clay from which terra cotta is made are buff and red, all other colors being obtained from the admixture of the above, or from the introduction of coloring matter, or by dipping the terra cotta into a colored slip before burning.

The disadvantages in the use of terra cotta are neither numerous nor insuperable, and may be summed up in the one word "time." Of course there is the difficulty of getting the blocks true, but this is a matter mainly for the manufacturer; at the same time much rests with the architect, in designing his plans suitable to the material.

Objectious have been made to terra cotta on the score of the extra time required to get up the necessary plans; one set of drawings for the builder, and another set to the shrinkage scale for the manufacturer. There is no absolute necessity for this. Makers are generally willing to undertake this. The full size drawing being thus all that is necessary, they being responsible under any circumstance for the delivery of the correct sized blocks. There are likewise risks in manufacture; some pieces may be destroyed in the very last stages. To prevent this we oftentimes make a few extra.

One great cause of complaint is the necessity of having the details of the work to be executed in terra cotta ready as soon as, or sooner than even the foundations are begun. In answer to this I will merely quote the words of Mr. Charles Barry.

He says, "Of these (that is the disadvantages) perhaps the most embarrassing is the arrangement necessary to have the terra cotta blocks made and ready on the ground before the rest of the work is begun, in order to work in when wanted as the bricklayers progress. At times this is found impossible, and annoying delays in the general work take place, for which clients will be apt to blame their architect. The lesson of course to be learnt from this is, to carefully mature the design at the outset, instead of contenting ourselves, as we now often do, with a mere sketch of what is intended, with the hope and intention of working in parts as time goes on and the work proceeds. I am not sure that architects ought to object to this, since it must produce decision of thought and precision of detail, which may be an advantage in an educational point of view, and is a serious corrective to indolence of thought in design."

Terra cotta has been objected to on account of its retaining its original color and not being toned down by age. Again I will quote an answer given by one of the profession. That if a design requires age before its beauties become apparent, it surely needs reconsideration. But this objection, I fancy, arose from the fact that some few years back it was considered that terra cotta should be very even in color, presenting the appearance of newly dressed stone ; whereas one of its great charms is its irregularity of color, a warm tint prevading its whole surface. White terra cotta can easily be made, but is not desirable ; it then becomes in appearance a mere imitation of stone ; whereas it possesses its distinctive features, which should never be lost sight of.

In designing for terra cotta buildings the nature of the material should always be remembered. Every block should be kept within reasonable limits, and large pieces only used where absolutely necessary, and unbroken lines as far as possible avoided. Large pieces may be made, but they are liable to warp and become expensive.

There are, of course, many kinds of work more suitable to terra cotta than others, such as terminals, ballusters, capitals, panels, trusses, articles which stand alone. Amongst other things it is made to do quite a new duty. In some parts of London it is used for names of streets. Plates, to show the position of fire plugs, have also been made ; but, though much approved, these have not yet been adopted in London—the reason, I believe, is that our Metropolitan Board of Works and the Water Companies find it would be an expensive affair to alter the many thousands of tablets, or even replace those that have become obliterated and useless, so each body shirks its responsibility. Every other material would require renewing at some time, but this is imperishable.

But perhaps the most difficult work we ever executed in terra cotta was a Doric portico, where the whole beauty of the design depends upon the straight lines, both horizontal and perpendicular, no break being allowed in the columns, which were about 7′0″ high. The only noticeable defect, however, was in the arch, where I expected none. The foundations were made a trifle too small, not more than 1½″, and the arches being thus a little too large, a true semi was not obtained, and though the keystone divided the blocks, the error was noticeable to a critical eye.

Stoneware, the subject we have next to treat upon, is a new adaptation of an old material, but, though it cannot boast the antiquity of terra cotta, dates back to a very remote period. It is thought by some that the slight glaze or smear on the Etruscan vases is due to the action of salt. Certain it is that in the excavations made in England several articles have been discovered salt glazed and of Roman origin.

The revival of this art, after many failures, is now being attempted with every prospect of success, and it is only a laudable pride to say that it is without doubt due to the spirit with which the work has been carried out at Lambeth, and the popularity with which it has been regarded. Although the Rhine pottery may have suggested the Doulton ware, the one is by no means a copy

of the other. The former is confined to a delicate blue body, with ornaments of deeper blue or purple, and only in the shape of mugs and jugs. The latter has a far greater range, both as regards colors and shapes.

The old system of salt glazing was like that now used in the Staffordshire potteries for obtaining the flown ware. The articles were placed in close seggars, and with them some salt and litharge, the fumes of which, given off when heated, coated the ware, but only slightly. The present method, and that pursued with the Rhine ware, is at a certain heat to throw salt into the fires, which becoming decomposed, one portion, the chlorine, escapes as vapor, while the other, the soda, meeting the white hot ware, incorporates itself with it, forming a glaze of such a delicate nature as not to obliterate the finest mark; it is this that makes it so useful in an art point of view. A rich effect is produced by sealing on flowers and dots, each one of which is put on separately by hand, while a wider range of color in the body of the ware is produced by various admixtures of clay, and by what is termed slipping,

The manufacture of these stoneware vases, pots, &c., for domestic purposes has now been carried on for the last four or five years with ever increasing success, and the fertility of design which our artists have displayed is surprising, there being no two alike. And you will be the better able to understand this when I tell you that some of the artists have designed and executed upwards of 8,000 pieces, each one varying from the other. One of the charms of this ware is that the ornament is designed and executed by one and the same person, thus the true spirit of the artist is never absent.

Amongst the many fields to which this class of ware seems to adapt itself is that of architecture. The failure of polished surfaces of the hardest material to retain their brilliancy in external decoration, especially in large towns, at once suggests its use as a substitute for polished granite and marbles; with this end in view we have made some bosses, ballusters, tiles, &c.

The various colors available must make this ware valuable to those who need variety of tint. These are rich brown, of several depths and clearness, blues of various intensities and opacity, blue green and clear deep green, pink, yellowish brown and clear gray. It is scarcely necessary to speak of the strength of stoneware, beyond saying that it is stronger than terra cotta, and more than able to bear any strain that would be possible to put upon it.

From the nature of this material, it may be easily understood that its cost would be more than terra cotta; but if compared with the cost of the materials for which it would be a substitute, such as polished marble or granite, it would be far less.

Thus I have endeavored to lay before you the merits and to some extent the demerits of these two materials, terra cotta and stoneware. The former may be considered to have established itself thoroughly as a building material, its daily increasing use being a sure criterion; but with the latter it is different, and its place in the future as a means of external or internal decoration depends much upon the favor or otherwise with which the architectural profession regard it. The manufacturing difficulties have been overcome, and a beautiful decorative material been produced; but what its future will be, remains with those whose duty it is to embellish our land with architectural structures, and in some measure to educate the tastes of those with whom they come in contact.

The new Victoria Dock at Dundee was opened with great ceremony, in presence of about 30,000 spectators, by the Earl of Strathmore. The dock, which is nearly opposite the North British Railway Station, covers an area of 10¾ acres. The north wall is 1340 ft. in length, the south wall 950 ft., and the west wall 410 ft., their depth being 31 ft. 6 in. The entrance dock, which communicates with the Camperdown Dock, is 320 ft. long, 60 ft. broad, and 28 ft. deep, and the depth of water in the dock at ordinary neap tides will be 18 ft. 6 in., and at spring tides 23 ft. The total cost of the works is £170,000, and they have been executed by Messrs. A. & K. Macdonald, contractors, Glasgow, in accordance with the plans of Mr. David Cunningham, engineer to the Harbor Trust.

SAGEBIEN'S WATER WHEEL.

From the "Universal Review of Mining."

The time is not far distant when one class of motors only will have to be considered ; when there will be but one theory applicable to motors of all kinds ; when this fact is recognized, viz., that there is only one power—if, indeed, there is one—attraction, that it manifests itself among invisible molecules or among visible bodies ; or rather that everything is in motion, and that this motion is continually transforming itself and transporting itself according to one single law, although susceptible of an infinity of applications. For a long time past, those who have had to design water-wheels have done so, keeping in mind only the endeavor to discover what speed it was which would give the maximum *useful power*. On the other hand, steam engines have been designed from an entirely different point of view ; the endeavor was to find out what should be the cycle of the evolutions of heat, in order to obtain the greatest *motive power* possible with a given expenditure of heat. Pambour was the first to introduce the element of speed into calculations relating to the steam engine ; that was a long while ago, but has he been followed in this direction ? We consider that the time is come to leave the beaten tracks and fill up the gaps which exist in the theory of motors ; to investigate the nature of the complete cycle (*cycle parfait*) giving the maximum of *motive power* in water-wheels as well as in heat engines, and the speed producing the maximum of *useful power* by means of a given motive power as well in water-wheels as in heat motors. But the laws of the maximum of motive power, as well as those of the maximum of useful power, will be the same for all engines. When this is done we shall be in a position to say that the theory of engines is decided, and this is what no one would dare to do at the present time. Indications have, however, been given which leave no doubt about what has just been advanced.

In fact it is well known that, in every engine with a reciprocating motion, there is a speed which gives the maximum of useful power. The relation which allows of this speed being estimated depends partly on the conditions of each particular case, but also on fixed general laws, which we have already laid down in this part of the *Review*. We have also pointed out, in our remarks on the experiment made by M. Lhoest, of Maestricht, that the transmission of power was effected by the same process, that the transmission of motion was attributable to that which we call gravity or to that which we call heat. In order to deprive a body in motion (visible or molecular) of all the *vis viva* of which it is capable within given limits of travel, it is necessary to oppose to it at each instant a resistance equal to its tendency to move, and thus encountering it at the commencement of the travel with a certain speed, to abandon it at the end of the travel with the same speed. Whether molecular or calorific phenomena are in question, this law is expressed by saying that the body which transmits molecular force (heat) from a cold to a hot body, through the intermediary action of an engine, should never be in contact with bodies which have any other temperature than itself. But if, on the other hand, the phenomena produced by visible bodies, such as the vertical motion of a quantity of water, be in question, the same law is expressed in other terms ; it is necessary that the resistance to the fall of the water be constantly equal to its tendency to fall, that is to say, to its weight. The conditions are the same, only they are expressed in two different ways. Whence the theory respecting water-wheels, and that of caloric engines have the same laws, or in other words, there is a *single theory as to the means of utilizing natural motions by the intermediary action of engines.*

Two men have brought to a practical result the knowledge which they possessed of this theory : Siemens, of whom we have just spoken, by the invention of his heat motor ; and Sagebien, of whom we shall now proceed to speak, by that of his water-wheel. Ths first,

however, has only made his *début*, and has not yet produced a commercially practical engine, while the Sagebien motor, which we shall now describe, is brought to perfection, and has for some time past achieved practical results.

So as not to leave our readers under the disagreeable impression that we have spoken in exaggerated terms, let us hasten to say that the trials made on several of the Sagebien wheels have given proofs that their useful power, measured with the dynamometer, has often attained, and even exceeded, 90 per cent. The names of those concerned in the trials vouch for the exactitude of the figures.*

On 25th December, 1861, Messrs. Tresca, Faure, Alcan, Delaye, Quinquet, Laforet, Lucas, and other competent practical men, took in hand very careful trials connected with the water-wheel erected by Sagebien and M. Sement, proprietor of a spinning-mill at Serquigny (Eure, France). With the ordinary method of gauging, and the co-efficient of contraction usually made use of, without mistrust, for water-wheels and turbines, the useful effect of the wheel was found to be 103.25 per cent., a result which was evidently incorrect. Sagebien pointed out that, if it were gauged by the method he applied to his wheel, which is a certain one, and which we will describe below, the reasonable useful effect of 93 per cent. would be arrived at. The conclusion to be drawn is that the useful effect of other water-wheels has been greatly exaggerated, through employing a fraction which is too small as co-efficient of contraction. Let us remark that the dynamometer was applied to a shaft mading 71 revolutions per minute, while the wheel only made about one and a-half revolution. There was then between the wheel and this shaft, a train of three geared wheels. M. Guy, principle of the *Ecole d' Arts et Métiers*, Chalons, proved, in the course of various trials, in 1863, a useful effect of 92, and even 95 per cent. He remarked that if he had adopted 0.64 as co-efficient of contraction, in accordance with the hand-books, the useful effect would have appeared as 102 to 103 per cent.; it followed, therefore, that the proper co-efficient was 0.7.

However that may be, M. Tresca, who had to report to the *Société d' Encouragement* upon the trials at Serquigny, found the results so surprising, that he dared not mention them, but commenced a series of trials on other wheels. It was only ten years afterwards that he became convinced, and published his work. We will extract from it the following table of the useful effect of the different water-wheels of Sagebien.

Water wheels of	Useful Effect.	Experimenters.
M. Pécourt, Amiens	0.90	De Marsilly.
Hydraulic Establishment of Amiens	0.94	Lienard.
Traill and Lawson, Beaurain	0.88	
Queste, Bonquerolles	0.85	
Small wheel (ten horse-power) at Chalons	0.93	
Raupp, Houlme	0.88	Slaweski.
Duboc, Cany	0.90	
Cœurderoy, Brionne	0.85	
Depoisses, Brionne	0.85	
Sement, Serquigny	0.93	Tresca, Faure, Alcan.
De Croix, Serquigny	0.82	De Bernay.
Greslé and Toury, Ivry	0.86	Hennezel and Leblanc
Saint Mars, Labruyere	0.85	Julien, Ponion.
Trilbardou (*in water raised for the purpose*)	0.70	Belgrand, Hult.

To these figures we will also add the following :

Forge-Thiry wheel	0.84
Maestricht wheel	0.93 and 0.877.

The first experiments were made by MM. Kraft, Powick, and Sagebien ; the second by M.M. Kraft, Devigne. L'hoest, and Sagebien.

The "perfect cycle" of a water-wheel is easy to determine. The water should flow from a higher reservoir, by a channel, to the wheel ; then, while fall-

* The Sagebien wheel was not exhibited at Vienna. There were only some imitations—so-called improvements; for it is possible to exceed 90 per cent. of useful power? Will not this figure alone suffice to excuse the mention of this wheel here?

ing, traverse the wheel, and finally deliver itself by a second channel, into a lower reservoir. The section of the inward channel should be calculated so as to deliver the desired volume of water, as also should that of the outward channel for its discharge. If they both have the same inclination, they should also have the same section, so that the speed at which the water flows should remain the same. The maximum of effective power will be obtained, if it be so contrived that in the wheel itself also the speed of the flowing water be the same, notwithstanding the acceleration which the force of gravity will tend to give it; for opposition offered to the existence of this acceleration is equivalent to the resistance of the wheel being at each instant equal to the power or the weight of the water. This condition is realized by the Sagebien wheel; whence it happens that its useful effect is so great.

But, to attain this end in a practical manner, what difficulties there are to be overcome! The water must, in the first place, be admitted without momentum, and without any change in level of the surface, and must then leave it quite spent. It is the surmounting of this difficulty, in fact, which forms the basis of all Sagebien's inventions, as will be seen by the writings of the inventor himself. We cannot do better than reproduce here what he says in a pamphlet published in 1866:

"This remarkable dynamic produce may be explained, if we consider that, in the system under notice, as will be seen below, there is no loss in fall, on the water flowing into the wheel, on account of the arrangement of the floats, into which the water is conveyed, without experiencing either contraction, alteration of level (*dénivellation*), if we may so call it, or agitation, so that the level of the volume of water which presses on the floats is maintained at the height of fall, in the same way as that which acts on turbines.

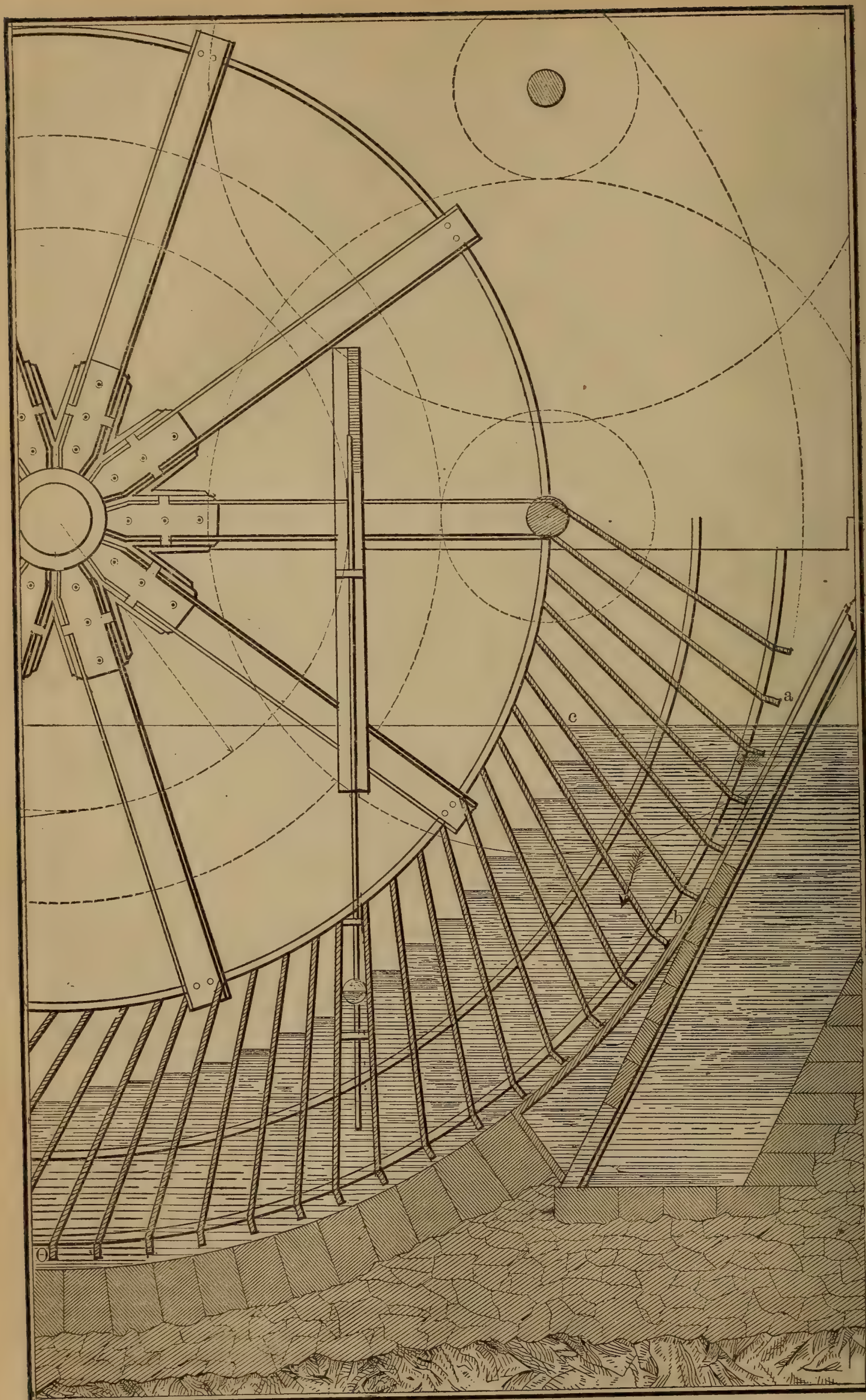
"In order to arrive at such a result, we rely upon this principle, viz., that if a tube be plunged into water, the liquid rises in the tube to the same level as it is immersed, and that the difference which manifests itself, during immersion, between the levels of the water without and within the tube, is so much greater as the tube is plunged into the water with greater speed. Calculations made in accordance with the law of gravitation establish the fact, that, by plunging the tube with a speed of 1 metre (3.28 ft.) per second, the depression of the water in the tube will be 0.051 metre (2 in.); that is to say, a pressure of 0.051 metre is required to produce a speed in the flowing water of 1 metre per second; for speeds of 0.7 metre (2 ft. 3½ in.), 0.6 metre (2 ft.), 0.5 metre (1 ft. 7½ in.), the depressions amount to 0.025 metre (0.984 in.), 0.0183 metre (0.72 in.), and 0.01274 metre (0.5 in.); while for a speed of 2 metres (78.742 in.) the depression will be as much as 0.204 metre (8 in.).

"Starting from this principle, the object is to hit upon such an arrangement, as that two consecutive floats may be regarded as a rectangular tube, which is plunged into the inflow channel or race, in as vertical a position as possible, so that the water shall take, by ascension, its level between the floats, in accordance with a speed corresponding to an insignificant depression, instead of doing its work by being poured over, as is the case in ordinary water-wheels.

"It was found to be practically impossible to plunge the floats in the water of the inflow race in a nearly vertical direction; we have, therefore, endeavored to find the minimum angle for that purpose, which would achieve the desired result, and we have discovered that an angle of 40° to 45° was sufficient, when combined with a speed of 0.5 to 0.6 metre (1 ft, 7½ in. to 2 ft.) per second, at the circumference of the wheel.

"Even under these conditions, however, the employment of the common straight floats, that is to say, those fixed perpendicularly to the circumference of the wheel, rendered it necessary to arrange the inflow very much below the centre of the wheel, so that the floats should make, with the higher race, the desired angle, which would require, in the case of inconsiderable falls, a wheel of enormous diameter. Such an arrangement, limiting the application of our system to small falls, could not afford us entire satisfaction.

"This consideration led us to con-



SAGEBIEN'S WATER WHEEL.

struct, in the case of falls greater than 0.6 metre (2 ft.), a wheel with inverted floats, as shown in the figure, so as to take the water at an angle sufficiently great to avoid any agitation of the water flowing on the floats ; and, thanks to this arrangement, we have been enabled to utilize falls of even 4 metres (13 ft.) with a wheel not exceeding 10 metres (about 33 ft.) in diameter.

"The inversion of the floats, which thus enter the water at an angle of about 45°, thoroughly satisfies this condition of maintaining, upon each one of them, the level of the inflow water in the same measure as they dip into it, until the moment when, arrived at the head of the wheel-race, or the sluice, they cease to take the water. The travel of the wheel from *a* to *b*, and that of the water on the float from *b* to *c*, to fill it, being very nearly equal in the same space of time, and the wheel having a speed at the circumference of 0.7 metre (27½ in.) per second, the alteration of level will be, at most, 0.025 metre (about 1 in.) But it will be seen further on, that, in practice, this slight loss becomes even much less.

"Now that the difficulty of taking the water without sensible alteration of level has been overcome, and as the outflow of water takes place without difficulty, it will be possible to increase the thickness of the water-space to an infinite extent, and consequently also the discharge, this latter being in proportion to the height of water in the floats.

"Our practice is generally, however, to keep this height within from 1 to 1.3 metre (3.28 to 4.26 ft.), which represents from 500 to 700 litres (110 to 154 gallons) of discharge per second, for every metre of breadth of wheel, and it is only when we have large volumes of water to discharge, that we arrange a height of water in the floats, which may attain to 2 metres (6½ ft.), in order to obtain a discharge of 1000 to 1200 litres (220 to 264 gallons) per second for every metre of breadth of wheel, with a speed of 0.8 metre (2.62 ft.) at the circumference.

"In order to turn to account the whole height of the fall, it would be necessary to sink the wheel to the level of the water in the floats; but it is often necessary to deviate from this principle when the flow of water is variable. In that case, inasmuch as it is advisable to turn to the greatest possible account the small flow of water during the summer, the height of the wheel is regulated to suit this case, while giving the floats an excess of height sufficient to absorb the water of winter, which may sometimes be double in volume ; but then, the water which will occupy this excess of height will not give the same dynamic effect, because at the point where the water leaves the curved portion of the race in its downward movement, a rush will be produced by the portion of water in excess, which corresponds to the loss of a portion of the total fall. We will remark, however, as a set-off, that when there is an abundance of water, there is a power at command in excess of that during the normal state, for which the motor was erected ; and, under these circumstances, there is less need to take particular account of the actual dynamic effect, which, moreover, even in this case, has been found to be never less than 80 per cent.

"It will be noticed, in examining the design of the wheel, that each float is terminated at its extreme end by another smaller float, 1 decimetre (nearly 4 in.) in height, the direction of which is towards the centre of the wheel. This arrangement has nothing to do with the useful effect ; it is only a simple precaution against accidents which must ensue from the passage of any body offering a resistance to the wheel. It is a fact that, if the floats were to retain the inclination which we give them to the very end, a piece of wood only, passing between the floats and the race, would be sufficient to produce a kind of buttress of such a nature as to cause great damage, while, in the present arrangement, the smaller float can yield to the obstacle and even break, if need be, without any further damage ensuing.

"On seeing the floats thus inverted and sunk so deep, one might be induced to suppose that on leaving the water they would take up a portion with them ; but this is by no means the case. The water flowing from the floats into the lower channel, follows the current without any indulation taking place,

and its motion is as unruffled, practically speaking, as that of the water flowing in from the upper channel. It would even seem that this inversion of the floats is favorable to the outflow so long as the speed of a metre per second at the circumference of the wheel be not exceeded. The water clears itself so much the more readily, as it takes from four to six seconds to be completely discharged in its flow from O to D. Let us remark, in addition, that the floats, as they issue from the surface, yield up, at first, but little water at the bottom of the race, at the point O, and that they continue to yield up more and more in proportion as they approach the point, D, where they yield it up altogether. The result is that the motion of the water as it issues from the float is found to be quite uniform with the normal flow along the channels, in which the speed is greater on the surface than at the bottom. If, now, we observe how the water enters the floats from the upper channel, and how it is yielded up into the lower channel, we shall acknowledge that it enters the wheel, keeping, at the same time, very nearly the same flow as that in both channels, since, in this its passage, the different layers of liquid preserve their relative positions, as well in the inflow race as that of the outflow; that is to say that the water taken at the surface of the higher channel, occupying the bottom space in the floats, is delivered on the surface of the lower channel; and also that the water taken at the bottom of the higher channel, which occupies the space between the extremities of the floats, is delivered at the bottom of the lower channel. We dwell upon this circumstance especially, so much the more because it tends to demonstrate the necessity of sinking the wheel as deep as possible, in order to turn to the greatest account all the advantage which this system is capable of affording.

"What we have just said explains the absence of all disturbed motion of the water, not only during its action on the float, but also even on its leaving the wheel; this is very different to what happens in the case of bucket wheels or those with ordinary radial floats, in which the water, independently of the shocks and resilience which take place during its action, has a tendency to strike on the bottom of the race, on leaving the wheel, before proceeding on its proper out-flow course; a circumstance which produces the undulation and resistance which may be observed by all.

"After the remarks we have made above, and the examination of the design of the wheel, it is easy to understand that this appliance is in a position to yield the greatest amount of useful effect that can possibly be obtained from a given fall and volume of water. It also seems to be the only one, hitherto, in which practice has borne out the conclusions of theory.

"One can account, at first sight, for the reason of this, by the mere comparison of our system with that of breast wheels with buckets.

"In fact, we see in our system:—1st, that there is a scarcely sensible alteration of level—not to say no alteration at all—in most cases, we shall presently explain; and that, in all cases, this is independent of the thickness of the water space round the wheel; 2nd, that the pressure of the whole body of the water is brought to bear instantly on the floats.

"In ordinary wheels, a far different state of things prevails. Thus, 1st, an alteration of level is observed, which is much more considerable as the body of water allowed to escape is thicker; and this thickness cannot always be reduced, especially in dealing with a great volume of water; 2nd, it cannot be exactly determined at what point in the wheel the full pressure of water is effective; in fact, inasmuch as the water always comes in contact with the buckets or the floats *in a fall*, the result is that according to the speed of the wheel, the water runs (within a certain limit) after itself, before its weight becomes effective; besides, in consequence of the shocks which it experiences in contact with the buckets or the floats, a portion of the water rebounds, and does not act effectively on the wheel until after it becomes settled, that is to say, at a point lower down.

"If, now, we take into consideration two causes of loss of useful dynamic force, common to both systems, that is to say, the friction on the gudgeons, and the escape of the water between the

the wheel and the sides of the race, the advantage is still on our side as in this case the losses become reduced as much as possible, in consequence of the low speed of the wheel and the slight perimeter of escape, compared with the volume of water given out; while breast wheels and those with buckets, are liable, on the one hand, to a greater loss by the friction of gudgeons (because they revolve at higher speed), and, on the other hand, to a much greater loss through the water escaping; because, as they take the water in as thin a body as possible, and are, consequently, of greater breadth, there is necessarily a greater proportion between the perimeter of escape, and the volume of water given out.

"Lastly, these wheels, as well as those of the Poncelet system, and turbines, both take the water and deliver it with shocks, bubblings, and splashes, which, taking place necessarily at the expense of the motive power, constitute only so much loss to be deducted from the useful dynamic effect, and, notwithstanding their importance, escape being taken into consideration in calculations. Whence it happens that the best applications of these systems have always shown a wide difference between the useful dynamic force really obtained, and that theoretically calculated.

"The same cannot be said of our system. The numerous experiments made with the dynamometer on different wheels have always shown a dynamic produce from 80 to 95 per cent. of the theoretical power."

With regard to the mechanical effect of the Serquigny wheel, M. Tresca says in his report, compiled after so many years of consideration:—"As to the trial made by your commissioners on M. Sement's wheel, for instance, they see no reason to reduce the figure, *which should be well noted*, viz., 93 per cent., as the average dynamic produce of M. Sagebien's wheels. As to the method of gauging devised by Sagebien in order to avoid the adoption of a co-efficient of construction evidently erroneous, we find in the same report:—

"The method of gauging which has best succeeded in the Sagebien wheels consists in the employment of a floating bulb which revolves with the wheel, and which is placed between two float-boards. The tail or rod of this floating bulb works up and down in guides, in the direction of the centre line of the space between the two float boards, and it is sufficiently long for its upper end to be visible at the instant it passes, in a vertical position, before the eyes of the experimenter. It has sufficient play within the guides, while, at the same time, its length of travel is limited, for the figure showing the height of water in the bucket wherein it is placed to be read at each revolution, so that an *absolutely correct estimation* can be obtained of the volume of water contained at a given moment in a given bucket. By multiplying the number thus obtained by the number of buckets, the total volume delivered by the wheel at each revolution will be known, and no error is possible unless, before reaching the position where it is to be gauged, the bucket should have lost a portion of the water which it had previously received.

Sagebien was enabled to calculate the amount of this loss by a hypothetical co-efficient for a certain amount of clearance between the ends of the float-boards and the race. Keeping in mind the large dimensions of the float-boards, the figure for correction is always of little value, and this method of gauging, which is readily applicable to all the wheels of M. Sagebien, offers the incalculable advantage of avoiding the use of the co-efficient of contraction, which other systems admit of, and which, in the case of overfalls from a weir, has always the disadvantage of a tolerably sufficient uncertainty."

M. Tresca also sums up, with great perspicuity, the advantages of the Sagebien wheel:

1.—The Sagebien system is eminently favorable to the utilization of small falls.

2.—Its effective dynamic produce not only attains but exceeds 80 per cent., even when the level of water varies greatly at different seasons, and the wheel must, consequently, be sunk very deep.

3.—This dynamic rusult is entirely ensured when the wheel only makes one and a-half to two revolutions per minute. This last rate of speed should not be exceeded.

4.—Notwithstanding the inconven-

ience of this low speed, the system under notice has, in several cases, afforded a dynamic effect exceeding 80 per cent., measuring the work given out on a shaft making 40 to 60 revolutions per minute.

5.—The breadth of the wheel, with an equal delivery, is much less than that of a breast wheel enclosed in a circular race, because water can be admitted into the wheel at a much greater height, which might, in certain cases, attain and even exceed two metres (about 6½ ft.)

We can add nothing to these words of appreciation, unless it be that M. Sagebien has crowned the system by his last improvement, which consists in the employment of a new method of governing. Up to the present time, all the hydraulic governors known limited their functions to acting on the sluice for regulating the flow of water. Now, it is a well-known fact that it is impossible to shut a sluice with a degree of haste, especially during a sudden acceleration, sufficient to obtain a sensible slackening, due regard being had to safety at the same time. The fact is, that a certain amount of time is necessary for the governor, as well as for a man's hand, to shut the sluice, and after this operation the water which has already flowed into the wheel will necessarily have its effect and prevent the speed from immediately diminishing.

It is for this reason that Sagebien arranges his governor to act at the same time on the regulating value of the wheel, and on a powerful brake bearing directly on the driving shaft so as to store up the excess of speed. This governor has been employed, with the greatest success, at the works of M. Régout, at Maestricht, and also in four works in the province of Liége.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers—Report on the Organization of a Mutual Benefit Society.—A Committee was appointed under the resolution of June 10th, 1875, to "investigate the feasibility and propriety of organizing the Society as a whole, or by voluntary membership, as a Mutual Benefit Society, to aid and benefit the families of deceased members."

The Committee recommends that a voluntary organization be formed within the Society, on the following basis:

1. The organization shall be styled the Civil Engineer's Insurance League. Its place of business shall be at the rooms of the American Society of Civil Engineers, in the city of New York.

2. No persons shall be admitted as members, except Members and Juniors of the American Society of Civil Engineers.

3. The officers of the League shall be a President, a Vice-President and three Directors, who shall choose a Secretary and Treasurer from among their own number. The officers shall be "Resident Members" of the American Society of Civil Engineers, and shall be elected annually on the first Wednesday of November, by a plurality vote of the members of the League present.

4. A statement of the business condition of the League shall be made by the officers on the first of November and first of May in each year.

5. There shall be an entrance fee paid by every person who may become a member. This shall be $5 for persons under 45 years of age, and $10 for persons over 45 years of age.

6. On receiving proof of the death of any member, the Secretary shall at once issue by mail a notification of such death to each member. The member so notified shall thereupon pay to the Treasurer the sum of $5. In default of such payment within 60 days after date of the sending of the notification by the Secretary, the person so defaulting shall forfeit membership in the League and his name shall be stricken from the roll.

7. Upon receiving proof of the death of a member, the Treasurer shall within 3 days thereafter transmit to the heirs or assigns of the deceased the sum of $500, and within 60 days thereafter the additional amount required to make the total sum equal to $5 for each member of the League who has responded to the assessment.

The Committee is of the opinion that the organization of such an association should not be made until 100 persons have signified their intention of joining the same, and to test the feasibility of forming such a League, recommend the passage of the following resolution:

Resolved: That the Secretary be directed to forward to each Member and Junior of the Society a copy of this report, and request a reply in this form, viz.:

I.. .... a (*Member* or *Junior*) of the American Society of Civil Engineers, ...become a member of a Civil Engineers' Insurance League, formed on the basis recommended in the report of the Committee presented November 3d, 1875.

Respectfully submitted,
W. E. Worthen, S. R. Probasco,
J. J. R. Croes,
Committee.

Among the late papers presented, were the following:—The Efficiency of Steam Vacuum Pumps by J. Foster Flagg; The Verrugas Bridge, by L. L. Chambote.

Institution of Mechanical Engineers.—The autumn meeting of the above institution was held in Manchester recently, at the Memorial Hall, Albert Square. In the absence of the President, the chair was occupied

by Mr. J. Ramsbottom, one of the past presidents.

After the election of officers for the ensuing year, the secretary of the institution (Mr. W. P. Marshall) read a paper, by Mr. W. Daniel, of Leeds, on mechanical ventilators for mines, in which the author said that in a paper on mining machinery read before the institution sixteen years ago, by the late Mr. T. J. Taylor, the ventilation of mines by furnaces placed at the bottom of upcast shafts, as compared with the mechanical appliances then in use, was for valid reasons considered the best and safest method. But, notwithstanding its admitted simplicity, the rarefaction of the outgoing air by heat to produce the ventilating current had proved troublesome, expensive and dangerous. Under these circumstances it was not surprising that, since the subject of mechanical ventilation was last brought before the institution, six years ago, the adoption of the greatly improved mechanical appliances then described for the ventilation of mines should have been so extensive, and that, in this country there were at present about 250 mechanical ventilators in actual use or in course of construction. In the matter of fuel consumption, the best existing appliances would be about on an equality with furnaces when the latter were employed at a depth of about 700 yards, and the less the depth the greater did the economy of the machine become; but it might certainly be asserted that the furnace ought never to be employed excepting in small mines, where the duration of working and physicial conditions were such as not to justify the additional outlay required for a fan. Most, if not all, of the mechanical ventilators at present in use exhaust from the top of the upcast shaft in the case of pits, or at the end of the return air-course, where they were employed for day working. The author submitted a statement of the results of experiments on some of the different systems for the mechanical ventilation of mines, and in conclusion called attention to the fact that, in the majority of ventilators now working, low pressures, very little expansion, and consequently wasteful types of engines, were usually employed where, owing to the almost constant work, a more economical engine might be advantageously adopted.

Mr. Charles Cochrane (Stourbridge) read a paper on the "Ultimate capacity of blast-furnaces," in which he said that in the course of a long investigation into the effective working capacity of furnaces, he had been led to conclude that there was an unmistakable source of falling off in the working of blast-furnaces not securely cased in iron, which had hitherto been overlooked, and which in such furnaces was the source of increasing loss the longer a furnace had been in blast.

Mr. L. A. Fletcher also read a paper on the construction, equipment and the setting of the Lancashire boiler.

The reading of the papers was followed by considerable discussion, and some formal business having been transacted the proceedings closed.—*Iron.*

IRON AND STEEL NOTES.

Basacolt and Roche's Steel Process.—This is the conversion into steel of a mixture of pig-iron and ore at a low temperature at the expense of the carbon contained in the pig-iron. The mixture is run in the liquid state into iron crucibles, where it is left to cool, being afterwards exposed to the heat of a cementing furnace brought to a cherry red. A double decomposition then takes place: the oxygenated compounds in the ore give up their oxygen, which combines with an equivalent of the carbon in the pig, and the latter is converted into steel by the excess of carbon and iron from the ore. There is no need for any special appliances, and the method is economical.

Iron in Russia.—The principal iron mines of Russia are situated in the Grand-Duchy of Finland, in the Oural, the basin of Olonetz in Central Russia, in Poland, and Southern Russia. Ironstone is not only found in mines but in the marshes of Finland and of south-western Russia in Volhynia. The ore is found mixed with organic substances, sand and clay earth. The entire absence of phosphoric acid adds to its excellent quality. Local makers extract by means of little open hearths or mere holes in the ground. The iron foundries in 1873 were 202 in number, blast-furnaces 150. Their product for that year was 336,430 tons of pig, 32,571 tons of castings, 260,959 tons of finished iron, 8188 tons of steel. The Russian founders are now showing great skill in utilizing old rails.

Hard Steel *versus* Soft Iron.—Mr. Isaac Reese, of this city, has an invention for cutting bars of hardened steel, and recently Professor B. S. Hedrick read before the American Association for the Advancement of Science, in session at Detroit, an essay on "The Requisite Amount of Simple Friction of Soft Iron against Cold Steel to Melt it." He said the development of heat by friction has been long known. For some time it has also been known that the operations of rubbing and rolling had the effect of changing the molecular structure of iron and steel. These operations will toughen and compact cold iron, and will harden and condense steel. Some time since Mr. Jacob Reese, of Pittsburgh, Pa., had occasion to construct a machine for cutting bars of cold-hardened steel. For this purpose he mounted a disc of about forty-two inches diameter, made of soft wrought iron upon a horizontal axis, so as to be rotated with great velocity. With any moderate speed no cutting was produced. But on giving the disc such a speed of rotation as to cause the periphery of the disc to move a velocity of about 25,000 ft. per minute—nearly five miles—the steel was rapidly cut, especially when the bar to be cut was slowly rotated against the disc. Sparks in a steady stream were thrown off. But on examining the pile of accumulated particles beneath the machine they were found to be welded together in the shape of a long cone, similar to the stalagmites in the lime-stone caves; they were nearly like the spikes of frost as formed in winter on Mount Washing-

ton, and illustrated at the Troy meeting. Real fusion takes place. The steel is melted by the swiftly moving smooth edge of the soft iron disc, but the disc itself is but little heated. The bar of steel on each side of the cut receives but a slight heat, not at all drawing the temper, or oxydizing it. By this process a rolled, polished and hardened steel bar of two or three inches in diameter may be cut in two in a few minutes. The soft metal disc of iron used was about forty-two inches in diameter. The particles fly off in thick jet or stream through which the naked hand may be passed without injury. They glance off without burning the hand, having assumed the condition which causes the spheroidal state of liquids.—*Pittsburgh Leader.*

RAILWAY NOTES.

The *Levant Herald* says:—"The working company of the Ottoman railways has, we learn, stopped the works which were in progress on the Shumla line, and which, after several years' delay, had at length been begun in October last. If we are rightly informed, the principal cause of this stoppage is the non-payment of the bi-monthly certificates presented by the company to the Government. These certificates having remained unliquidated for more than six months past, the company has, it appears, found it impossible to go on making advances to the Government for the execution of the works, and is now compelled to dismiss its workmen. Under any circumstances this step is to be regretted—the more so since it is always much less easy to take up again works which have been suspended than to carry them out interruptedly. The Shumla line, which according to the existing contract, ought to have been completed at this very time—that is to say, by the 18th of May, 1875—is of peculiar interest to our public, inasmuch as it would have put Constantinople in railway communcation with the rest of Europe, through its junction at one end with the Yamboli line, which is already being worked, and at the other with the railway from Varna to Roustchouk. In a strategical point of view, moreover, it would have been desirable that the stronghold of Shumla should have been connected as soon as possible by rail with the interior of the empire."

ENGINEERING STRUCTURES.

While Mr. James Anthony Froude, says the *Inter-ocean*, has undertaken to turn the current of British emigration from America and Australia to the possessions of her Majesty in South Africa, Captain Sir John Glover has conceived a bold project for the civilization of the same part of the globe. This scheme is the formation of a canal for commercial purposes from the mouth of the river Belta, on the Atlantic, in the neighborhood of Inby and Cape Bajador, opposite the Canary Islands, to the nothern bend of the Niger at Timbuctoo, a distance of 740 miles. Such a highway would open up the African continent to the world, and it is believed that no formidable obstacle opposes the construction of the work, but that the great Desert of Sahara favors it. For 630 miles of the distance there is a large hollow, supposed to be 250ft below the level of the Atlantic ocean, which was probably at one time covered by the sea. The low country is separated from the coast by a broken ridge of about thirty miles, through which the river Belta runs for twenty-five miles, so that all that would be necessary to reach it is to deepen the channel of the river, cut through the ridge, and let the waters of the Atlantic fall into the vast arid basin. In this way a fine sheet of water would be formed, the climate would be improved, the country would become more fertile for pasturage and agriculture, and commerce would be carried into the heart of Africa. It is a fine project, second, says Sir John Glover, only to the Suez Canal; but very much remains to be done before its practicability can be considered certain. Its author, Mr. Donald Mackenzie, proposes to organize an expedition to establish a station at the mouth of the river Belta, in the first instance, and then make a scientific survey of the country. If it could be shown on good independent authority, that the scheme can be executed at a reasonable cost, there is no doubt that the enterprise of England would prove equal to such a work.—*Engineer.*

Hydraulic Lifts on Canals.—The trustees of the River Weaver Navigation attended on Wednesday last the formal opening of a hydraulic lift for vessels, which forms a new and most important improvement in canal navigation. The site of this new invention is at Anderton, where the Trent and Mersey Canal, on its way to Runcorn, approaches the river Weaver. There is already a considerable trade passing from the canal to the river at Anderton, proceeding from the iron and pottery districts to the sea at Liverpool; but, as the canal is over 50 feet above the river, the whole of this trade has hitherto been subject to transhipment, which necessarily involves a great expenditure upon labor. The object of the trustees has been to raise the river vessels at one sheer lift up to the level of the canal, and to lower the canal vessels by the same means to the river, thus establishing as complete intercommunication between canal and river as if no difference of level existed. With this view their engineer, Mr. E. Leader Williams, C. E. (now engineer to the Bridgewater Trust), placed himself in communication with Mr. Edwin Clark, C. E., of London, and Mr. J. T. Emmerson, of Stockport and Liverpool, who are respectively the designer and builder of the great hydraulic ship docks of Malta and Bombay; and these gentlemen undertook, in co-operation with Mr. Williams, to fulfil the wishes of the trustees in a successful manner. They have accordingly formed an extension of the canal in two branches towards the river in wrought iron, and adjacent to these, and capable of direct water communication with them, have placed a double lift, which takes the vessels, up and down by means of hydraulic power actuated by steam. The lift consist

of two large wrought iron tanks, or open pontoons, situated side by side, and each of equal section with the canal, and of a length sufficient to receive the longest of the vessels which navigate the canal. One pontoon ascends while the other descends, the time occupied in making the ascent and descent being on an average only about three minutes. Each pontoon is fitted with ends that lift up when connection has to be made with the canal or the river, thus allowing a free passage for the vessels out of or into either. These lifting ends, and the junctions of the pontoons with the iron branches of the canal, are all made perfectly watertight by means of very ingenious arrangements of india-rubber packings, which are brought into operation by the motions of the lift and the pressure of the water. The work has been carried out by Messrs. Emmerson, Murgatroyd & Co., under the inspection of Mr. James Watt Sandemann, C. E., the present engineer of the Weaver Trust. Several vessels were taken up and down with rapidity, and the satisfaction felt with the operation was general and complete. It is considered that this means of direct connection between the canal and the river Weaver will greatly increase the trade and income of the latter. —*Architect.*

ORDNANCE AND NAVAL.

THE COLBERT, which is an armour-clad of first class, was launched a short time since at Brest. This vessel was built from designs by M. Dupuy de Lome, modified by Messrs. Sabattier and d'Amtly, and was laid down in 1869, and thus has occupied nearly 6¼ years in construction. Her length is 102 metres, breadth of beam 18 metres, and mean draft 8 metres; she is fitted with engines of 1000-horse power. This vessel is armed with 4 mitrailleuses, 6 guns of 27 centimetres calibre for the central turrets, 2 guns of same calibre for side turrets, 1 gun of 24 centimetres, and 6 of 14 centimetres on main deck. The Colbert and Richelieu, recently built at Toulon, are the only vessels of this type in the French navy. The total cost of this vessel completely equipped is estimatted at 8 million of francs (£320,000).

THE THUNDERER, double turret monitor, has not come out perfectly unscathed from the protracted and severe trials to which her 38-ton guns and the working gear have been subjected. In consequence of the severe concussion of the guns when depressed, some of the T-iron beams which support the superstructure have been loosened from the bolts which secure them to the sides of the ship, while cracks have shown themselves in the welding at the ends. The fissures in no way affect the turrets, which are independent of the superstructure. The injury is wholly due to the explosion of the enormous powder charge sweeping over the deck. At Devonport a short time ago the depressed fire of a turret ship tore open the deck. As the result of his experience on board the Devastation during her passage to Malta, Mr. Barnaby, director of naval construction, has recommended that the Thunderer should be furnished with a patent cable controller, the present arrangement being extremely dangerous to human life on the anchors being let go. The four spocket wheels over which the cables pass will be all on the same shaft, and will be checked either singly or together by the controller, which will be worked by the capstain engine.—*Engineering.*

A GUN PLOUGH.—A prophecy, says an American contemporary, ascribed to both Isaiah and Micah, foretels that the approach of the era of good will upon earth shall be hailed when men "shall beat their swords into plough-shares, and their spears into pruning hooks." We fear that the faith of believers in the speedy advent of this period will receive a shock on reading the account given below of a cunningly devised anti-millennial device. Unmindful of the prophecy referred to, on June 17, 1862, C. M. French and W. H. Faucher obtained letters-patent for a combined plough and gun. The utility of this formidable agricultural implement is expected to assert itself in "border localities subject to savage feuds and guerilla warfare. As a means of defence in repelling surprises and skirmishing attacks on those engaged in a peaceful avocation, it is unrivalled, as it can be immediately brought into action by disengaging the team, and in times of danger may be used in the field, ready charged with its deadly missiles of ball or grape." The stock of the plough is the gun, and the share serves to anchor it firmly in the ground, the handles in the rear being brought into requisition in aiming the gun. At this distance from scenes of "savage feuds" we are, perhaps, not able to appreciate this invention ; but that it is an agricultural curiosity we must admit. We may next hear of war-like milk-pails for Amazonian dairy women.

BOOK NOTICES.

CHEMICAL EXAMINATION OF ALCOHOLIC LIQUORS. By ALBERT B. PRESCOTT, M. D. New York : D. Van Nostrand, Price, $1.50.

The objects of this manual, as stated in the preface, are to give in outline the chemistry of alcoholic liquors, including their current impurities and adulterations, in such terms as to be understood by persons having only an ordinary acquaintance with chemical science ; and secondly, to furnish directions, as far as possible, for an efficient chemical examination; not more elaborate than is required for commercial, hygienic and legal purposes, and containing all details except such as are to be found in every rudimentary treatise on chemical analysis. The writer, we are happy to find, holds it to be of absolute importance to society that all articles used as foods, medicines or beverages be made subject to strict examination by authority of the law, and that impurities and additions be systematically exposed and suppressed. The author carries out his plan in a very satisfactory manner. Under each alcoholic liquor he describes the normal constituents, and then the fraudulent additions or substitutions.

Thus we are informed that genuine wine (the fermented juice of the grape without any addition) contains:—

(*a*). Alcohol, 7 to 20 per cent. by weight.

(*b*). Non-volatile substances, 3 to 10 per cent., including—

- Grape-sugar 0.1 to 3 per cent. (in a few varieties of wine 10, 13, 14 per cent.)
- Free fixed acid, equal 0.3 to 0.6 of tartaric.
- Tanic acid, 0.08 to 0.20 per cent.
- Glycerine, 0.1 to 0.5 (maximum 2.0 per cent.)
- Albumen (nitrogen from 0.02 to 0.06 per cent.)
- Gum. pectin, fat, wax, color, ash, 0.17 to 0.27 per cent. (Potassic phosphate, fully two-thirds the ash.)
- Tartrate of ethyl (decomposed upon evaporation.)

(*c*). Volatile substances, besides alcohol and water.

- Ethers.
- Fusel oil.
- Acetic acid (0.06 to 0.12 per cent.)

We must remark that the author does not use the term "fusel" as a mere synonym for amylic alcohol, but extends it to all those products of fermentation which distil at a temperature higher than the boiling-point of ethylic alcohol. He quotes from Schmidt's "Jahrbucher Gesam. Med.," 1871, B. 149, p. 264, some interesting information on the physiological action of these compounds, which fully confirms the prevalent notion of their insalubrity. Amylic alcohol, it appears, produces poisonous effects, closely resembling those of ethylic alcohol, but of fifteen times greater intensity. Frogs were floated in a 0.002 solution of the alcohol (one part to 500 parts of water), and then in stronger solutions, and the effects of depressed action of the heart, congestion, anæsthesia, and death were timed. Amylic alcohol produced the same effects in the same time as did ethylic alcohol of fifteen times greater concentration or butylic alcohol of three times greater concentration; from which it was inferred that the poisonous action of butylic alcohol is five times more intense than that of ethylic alcohol in the same quantity. Rabuteau also experimented on himself, taking from four to eight grains of amylic alcohol in a glass of wine, and the results confirmed the conclusions given above. On the other hand, Hermann, in his "Alcoholism in Russia," maintains that *delirium tremens* and acute alcoholism are not found more likely to result from the use of cheap spirits with much fusel oil than from the consumption of the purer qualities. We may here state that in Poland and certain parts of eastern Germany, where highly fuseliferous potato-spirit is extensively consumed, the belief in its specially injurious character is common, both among professional and non-professional characters.

Apropos of poisonous beverages, our attention naturally turns to the worst of the class, absinthe. Dr. Prescott describes it as containing 40 to 60 per cent. by volume of alcohol, and several per cent. of essential oils, those of wormwood, cinnamon, cloves, anise, and angelica being chiefly used, and colored green with leaves of spinach and parsley, occasionally also with acetate of copper or with a mixture of indigo and gamboge. Doubtless by an oversight, he makes no allusion to the specifically noxious quality of this liquor as compared with alcohol. We certainly think it essential that the manufacture, importation or sale of this and of any analogous compound should be, on obvious sanitary grounds, totally prohibited.

Returning to wine, we find, among the list of impurities or additions, sugar to increase the alcoholic strength of wines which would otherwise be weak. The author mentions that not more than 20 per cent. of alcohol can be obtained by fermentation. If a greater amount be detected, the wine is sophisticated by the addition of spirits, generally of a low quality. Glycerine is occasionally added to the extent of 1 to 3 per cent., and if of good quality, free from traces of lead, is one of the most pardonable additions.

Calcined Gypsum is sometimes added "to prevent viscous fermentation, to restore ropy wines, to fix color, and to remove water." It is sometimes sprinkled upon the grapes, constituting the sin of plastering. This evil practice has not only been long and widely followed by the manufacturers—we use the term advisedly instead of growers—of sherry, but is finding its way into Australia. The result is that sulphate of potash is formed in the wine to an unnatural extent; its harsh, saline bitterness greatly injuring the flavor, and its well known action upon the heart rendering it hurtful, even dangerous. We should propose that all wines found to contain sulphuric acid in combination that above the normal amount should be at once condemned and run out into the river. Of course a brisk debate would then arise as to the normal quantity, and those chemists who stated the amount correctly would be pronounced "incompetent" by self-constituted judges. It is an important fact that in the juice of the grape magnesian salts predominate, whilst the fruits with which spurious imitations are chiefly got up are richer in calcium compounds. True wine contains malic and tartaric acids, whilst sham wines are often rich in citric and *horribile dictu* in oxalic. The latter prevails when the fermented juice of rhubarb plays a leading part in the manufacture. Cane-sugar is never found in gunuine wine, and its presence is, therefore, a mark of fraud. The author very judiciously remarks that "the artificial production of wines is not, like that of brandy, a task which chemical skill can hope to accomplish. Besides the great complexity of the ethers, the solid extractives are requisite. Then the peculiarity—in many cases the commercial value, of an actual wine depends upon certain proportions of the constituents named above, which proportions the chemist cannot fully determine. The ethers of wine elude quantitative analysis. Moreover, there are doubtless substances in wine not identified. It may be perfectly true that a mixture of pure alcohol, water, glucose, bitartrate, and ethers, may be made in such carefully adjusted proportions that it will prob-

ably be capable of producing whatever effect wine would produce upon the system, and indeed may be less objectionable for administration, more agreeable and more saleable than are many grades of actual wine; yet such a mixture is not actual wine, and should not be presented as such."

In treating of malt liquors, the author does not endorse the view that strychnia, if added to beer, would be thrown out of solution by the tannic acid of the hop. The tannin of the hop does not remain beer. "Moreover, the insolubility of the tannate of strychnia in 20,000 parts of water is by no means assured, and with the solvent action of acetic acid, as in beer, is quite improbable." Further, where strychnia is used, the hops will either be greatly reduced in amount or dispensed with altogether.

We may finally characterise this work as a valuable complement to the labors of Mr. Allen, Professor Wanklyn, and others of the much-abused public analysts who are successfully striving to place the chemical examination of food upon a sound and sure basis.—*Quarterly Journal of Science.*

NOUVELLE MECANIQUE INDUSTRIELLE. Par M. LEON POCHET. Paris: Dunod. For sale by D. Van Nostrand.

This work presents in the fullest manner the theory and practical working of the different heat motors, such as steam engines, hot air engines, gas engines and injectors, together with a full discussion of the performances of compressed air motors.

The chapter on injectors is a complete treatise on the subject. Wherever in the work formulas are deduced by the theoretical discussion, practical examples are made to follow in order to illustrate and apply the principle. The work contains 400 pages of text, illustrated by about 80 wood cuts.

THE CHOLERA EPIDEMIC OF 1873 IN THE UNITED STATES.

A—History of the Cholera Epidemic of 1873 in the United States, by Ely McClellan, M. D., Assistant Surgeon U. S. A.

B—History of the travels of Asiatic Cholera, by John C. Peters, M. D., Ass't Surgeon U. S. A., and Ely McClellan, M. D., Ass't Surgeon U. S. A.

C—Bibliography of Cholera, by John S. Billings, M. D., Ass't Surgeon U. S. A. Washington: Government Printing Office.

The above reports were prepared under the direction of the Surgeon General, and are liable to be regarded by the public as possessing no interest except for practising physicians and health officers. The briefest examination however, of either of the first two reports will convince the reader that no one can afford to dismiss with slight inspection, such masterly records of the work of this great destroyer.

Modern medical science teaches lessons of prevention, and a great epidemic is no longer regarded as an unavoidable *visitation*, except by the ignorant and the superstitious.

This greatest of all epidemics, is proven by these reports to be perfectly controllable by human foresight; its march over the world may be absolutely arrested.

The account of the last visit of true cholera is quite voluminous, but the chain of circumstantial evidence, that it was transplanted from Europe and then propagated through neglect of proper precautionary measures, is presented with admirable skill, the details of cases are given with appropriate brevity, and the proof of a common origin of them all is afforded by the collated testimony, and rendered wonderfully clear by numerous maps. It appears that although this epidemic visited seventeen states and territories, New York and the Eastern States were exempt.

But the portion of the work of most absorbing interest, is that relating to the history of the former regular and steady marches of this terrible scourge; its beginning with the great religious pilgrimages in India, and progressing with terrible regularity along the great avenues of trade and travel, until it had encircled the world, the story is told with graphic power.

The map illustrations are quite abundant and of unusual clearness for a public document.

SCIENCE SERIES NO. 20. BRIDGE AND TUNNEL CENTRES. By JOHN B. MCMASTER, C. E. New York: D. Van Nostrand. Price, 50cts.

This work has already commended itself to readers of the Magazine, having been recently printed entire. It is believed to be more complete and practical than any other work so accessible to the practical engineer. The preface to the book which was not given with the Magazine articles, is herewith appended:

"It is the purpose of the following essay to present in as brief a manner as the nature of the subject will allow, the rules and principles, the application and observance of which is of really vital importance in the planning and construction of Bridge and Tunnel Centring. It is not offered as a highly elaborated and exhaustive treatise on this branch of engineering, nor is it intended to furnish a variety of designs likely to be useful to the carpenter and bridge-builder; it does not claim to be analytical; it is purely practical.

Very much, therefore, of what, under other circumstances, might most fittingly have been introduced, has been carefully omitted, and nothing set down which does not bear directly on the subject in hand, and had not been verified, time and again, by actual experiment. It will be observed, for instance, that what may be termed the mathematics of the subject finds no place here. There are no mathematical demonstrations, no lengthy discussions of the various formulæ introduced; they are simply set down as expressing established truths, the proof of their correctness in many cases suppressed, and the reader requested to accept them as true. In the form in which this essay first appeared, this was done to save space; in the present form it has been strictly adhered to, because it is believed that those to whom the work will be of the most use, are precisely those who will be content to take as true the formulæ given, caring very little for the steps by which it has been reached.

In connection with the matter of estimating the load on a centre, four methods have been selected, either of which will give results close enough to the absolute truth for all practical purposes. The first, that of M. Couplet, is extremely simple, and if it errs at all, does so on the side of safety. The second or "graphical" is constantly growing in favor, and most deservedly so; the third, that by calculus, disregards friction and gives results greatly in excess of the truth, while the fourth, or trigonometrical, is perhaps the most exact of all, and admits the application of logarithms.

The remarks on the subject of uncentring are believed to be sufficiently extended, though the subject is one of great importance. The principles, however, to be observed in striking centres are quite few and simple, the observance being all that is necessary to secure success. The sand method cannot be too highly commended.

The remarks coming under the head of tunnel centres, have been limited to pointing out the essential difference between the centre proper for bridging, and that suitable for tunnelling, to calling attention to the peculiar variability of the strains, and to the care to be observed in guarding against the accidents so liable to produce injury to the ribs, and to offering a few practical suggestions as to economy. A few designs have also been added as illustrative of the principles laid down, and as affording examples of cheap and durable frames. The patent centre of Mr. Frazer is worthy of some attention."

The illustrations are numerous and excellent.

SCIENCE SERIES No. 21. SAFETY VALVES. By R. H. BUEL. New York: D. Van Nostrand. Price, 50cts.

This is a reprint of the articles recently published in the *Railway Gazette.*

It is quite exhaustive on the subject of safety valves, and what is more to the purpose, the author's rules and formulas are reliable.

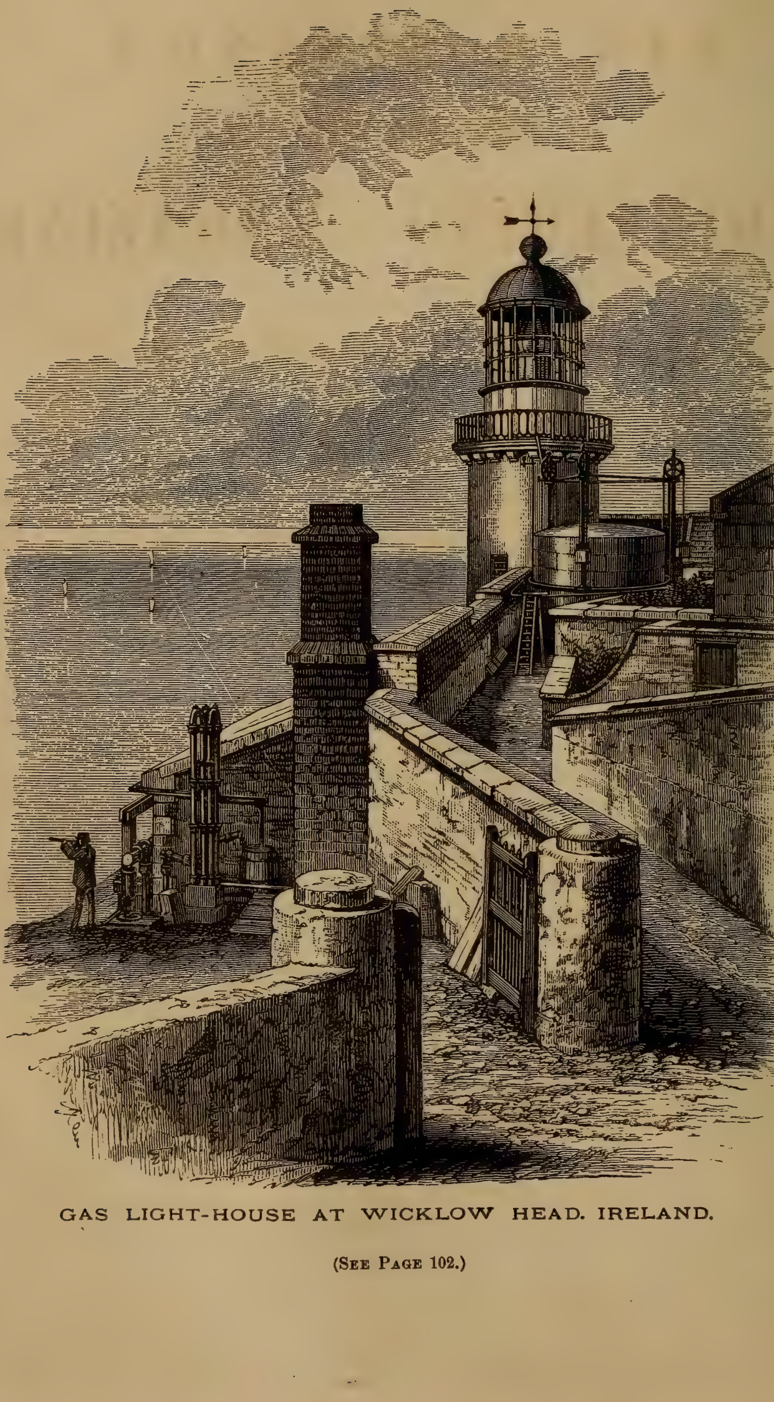
Builders, inspectors and owners of steam engines are equally interested with engineers in this subject, and may find in this short treatise a safe instructor and a guide to practice. The author fully explains his views in the following brief preface:

"The writer, in presenting these remarks to engineers, does not pretend to offer much that is original, but has aimed to gather what is valuable from the great mass of material to be found in scientific periodicals and in publications that are not generally accessible. An endeavor has been made to systematize the treatment of the subject, and to give such varied solutions of the problem that arise in proportioning the parts of safety valves as to render them plain to those who have only an elementary education. The importance of having the general principles of safely valves understood by those who are charged with the care of steam machinery cannot well be overestimated. With a safety valve that is in reality all which its name implies, a large proportion of the risks incident to the use of boilers will be avoided; while on the other hand, a safety valve that is only such in name is one of the readiest assistants to a disastrous boiler explosion."

MISCELLANEOUS.

THE annual import of Bath bricks into the United States is about 10,000 boxes, 24 bricks in a box. Formerly they went in bulk; but so many got broken that it was deemed advisable to have them securely packed. These bricks are manufactured from the deposits of the river Parrett, Bridgewater, Somerset, where millions are made annually. Nowhere else is this deposit found, so that Bridgewater supplies the world, and Bath bricks are as well known in America, China and India as in England.

METAL WORK AMONG THE HINDOOS.—For several centuries India has enjoyed the reputation of having produced some of the most tasteful, if not the finest quality of armor; and the manufacture of swords, spears, daggers, warlike weapons, elephant goads, state umbrella handles, chain-armor, and insignia of rank, has given employment to skilled workmen all over the country. As in Europe in olden times, the chief encouragement has come from the princes, nobles, and zemindars, or wealthy land owners, who have usually kept in their employ skilled workmen and their families, who have devoted all their time and talents to the perfecting of some particular branch of industry. It is for this reason, says Dr. Hunter, in the *Art Journal*, that we often see an amount of labor, manipulative skill and taste expended upon single small articles of little intrinsic value, which would not have been produced to meet the requirements of the ordinary market; but where the workmen have been in the employ of some wealthy rajah, upon whose bounty the whole family has been dependent, time and labor were not of so much consequence as manipulative skill and tasteful finish. This principle has been applied to nearly all the best art industries of India, and the result has been that large families have been trained for successive generations to particular industries, which have been carefully retained, fostered, and brought to perfection in particular districts or villages. Caste prejudices have also contributed in no small degree to keep up the practice, which has some good points to recommend it, though there are objections to the system also, the most serious of which has been that an industry has often died out in a village by the death of the rajah who encouraged it, or on the death of the most skilled workmen. The finest coats-of-mail and chain-armor have been produced in Upper India, and the helmets, cuirasses, shields, armlets, and gauntlets, inlaid with gold, are often most tastefully decorated. The localities where these manufactures attained to the greatest perfection were the Punjab, Umritsur, Delhi, Cashmere and Nagpore. Small weapons, as swords, daggers, battle-axes, elephant goads, and insignia of royalty or of wealth or rank, have been made all over India, and the courts of Hyderabad-Tanjore, Vizianagram, Travancore, Poodoocotta, and many others have encouraged these and similar manufactures.—*Builder.*



GAS LIGHT-HOUSE AT WICKLOW HEAD. IRELAND.

(SEE PAGE 102.)

// VAN NOSTRAND'S

ECLECTIC

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LIGHT-HOUSES.*

Good light-houses are legitimate objects of national pride; monuments alike of engineering skill and of the nation's regard for the commerce of the seas, they are conspicuous indices of advanced civilization.

A healthful rivalry at present exists between the leading European nations in the matter of lighting their coasts; each, however, adopting any well tried improvement independent of its origin. That the efforts of our own country are in the right direction may be inferred from the character of the report of Maj. Elliot, made as it was under the direction of the Secretary of the Treasury. The extent and thoroughness of this tour of inspection is an earnest of the intention on part of our Government to compete in this peaceful strife.

Already have we contributed something both in the way of signaling and in the matter of foundations for the more common forms of light-house structures on bars or shores of low altitude; but the report assures us "both England and France are in advance of us in using both gas and electric lights in positions of special importance—in the use of azimuthal condensing prisms for certain localities; in the character of their lamps; in the use of fog-signals in light-ships; in their light-ships with revolving lights; and, more than all, in the character of their keepers, who are in service during good behavior until death or superannuation, who are promoted for merit, and whose lives are insured by the Government for the benefit of their families."

Of the character of the problems to be solved in lighting a coast and of the general method of solving them, we can give no better idea than by quoting from our cotemporary, *The Building News*, an account of the French system of light-houses, simply premising that in all that pertains to the most advanced ideas in this branch of engineering, our Gothic friends have no superiors:

"France, it may now be said, has almost completed her lighthouse system, ranging from Dunkirk to Socoa, from Port Vendres to Nice, and, taken as a whole, it exhibits a marvel, at once, of national enterprise and of engineering ingenuity. As is well known, an entirely new science and practice have been created, of recent years, with respect to these beacons, warning the mariner of his approach to land of any kind; but especially to capes, headlands, reefs, and shallows. It is now the established custom to erect the loftiest structures, bearing the most powerful lights, upon the most elevated promontories, or nearest to the most dangerous rocks, and to

* European Light-House Systems; being a Report of a Tour of Inspection in 1873, by Maj. Geo. H. Elliot, Corps of Engineers, U. S. A. New York: D. Van Nostrand.

plant them at such distances one from another that it would be next to impossible, assuming commonly careful seamanship, or a fog so dense as to be impenetrable by either natural or artificial light, that the shore should be approached without one or another being seen. By arranging, from point to point, the alternating flashes and obscurations of the lamps a guide is given to the vessel, which, if studiously followed, proves generally a perfect safeguard. Along the bays, however, necessarily intervening between these principal edifices, and into which sea-going ships need not enter, are supplied, for the sake of coasters and small craft, illuminations of a second and third-rate order, indicating perilous thrusts of the land into the sea, hidden rocks, and sandbanks, and the entrances to harbors and ports. Thus the coast of the Gironde, an immense resort of commerce, has no fewer than eleven light-houses of the three classes, with others of yet a different description, being simply signal-lanterns, hoisted above quays and piers, to signify whether or not they may be safely approached. But it is not with the nature of the lamps, the colors of the lights, or the character of the oil, or the apparatus employed, that the last report deals in its most important sections : it is with the structures themselves. They should, say the Commission of Light-house Architects, be so built as to satisfy numerous difficult conditions. They must be lofty, in order that the sailor may perceive, from a distance, their friendly flames. Occasionally, it may happen that they can be pitched upon the summit of some natural height, as that on Cape Bearn, or on the crest of a cliff, as those of Ailly, Fécamp, and Heve, on the Norman coast, in which case it suffices that the tower shall be high enough for its lantern not to be concealed by trees, churches, or houses, or liable to be damaged by mischief-doers. But frequently the necessities of navigation render it compulsory that the light-house should be built on the very edge of the sea, or even upon a rock, or group of rocks, whose surface is level with the water. Here the same necessity exists for a considerable altitude, since no French light-house, of the first-class, is regarded as effective unless its beacon burns at an elevation of at least a hundred feet above the level of the sea. The principal of them, however, are much loftier—that of Cordouan 200, which all but tops the towers of Notre-Dame ; that of Dunkirk, 175 ; that of Calais, 160 ; and that on the Isle de Ré, the same. Practically, it is found difficult, if not impossible, that these slender edifices should possess, in all their height, the qualities of massiveness and enduring solidity ; and it is all the more necessary, therefore, we are reminded, that their construction should be the most elaborate, and, above all, their foundations reared as if intended to be fortresses to resist the attacks of the sea. This, however, as is recorded in the annals of some among our more famous English edifices of the kind, is particularly difficult when the basis is a sand-bank, liable to shifting or submersion. The weight to be borne, it must be remembered, is not that of the lantern alone. There must be store-rooms, stores, apartments for the keepers, and so forth. Moreover, scarcely any structure of the sort was ever piled up which did not, at times, reel and bend beneath the violence of the tempest—a fact calling for the utmost possible perfection of masonry ; yet, in spite of all, the doom of not a few is already pronounced. For example, the central light-house of Cape Ailly has been declared, notwithstanding its slimness, its thick walls, so harmonious in proportion, so little weakened by the internal staircase and external windows, that it seemed destined to stand for ages. But the Cape of chalk, whence it rises, has, since its construction, been more than half demolished by the waves, and the day must certainly come when that Norman Pharos must fall headlong into the waters—a circumstance upon which the Architectural Commissioners comment in discussing the question of future sites. Still more remarkable than this, however, is the Tower of Cordouan, at the mouth of the Garonne, which has stood since the end of the sixteenth century, on a rock covered, at high tide, by 12ft. of water. The architect made of it a labor of love, and lavished upon it an excess of decoration. His original building was only 100ft. high, and mariners complained that they could not see the light from sufficiently far. Two

centuries later a daring architect proposed to make it 80ft. higher, and to rear above the sculptured chambers of the first and second stories an additional structure, obelisk-shaped, the joining of the old with the new being guaranteed by him to produce no cause of weakness. His pledge was fulfilled. No "weakest point" was ever proved in the Tower of Cordouan. As to the processes by which this marvelous edifice was erected, there exist, unfortunately, no records. Another celebrated French light-house is that of Fléaux de Brehat, a recent erection, based upon a huge and treacherous porphyry rock, for ages the terror of every seaman who approached the Brittany coast. Its architect had to encounter every species of obstacle during his work, but, above all, incessant races and eddies of the sea among the neighboring sandbanks. The foundations had to be sought for far beneath low-water ; an artificial port had to be created ; the necessary stonework was hewn and shaped on the Island of Brehat, seven miles distant. Even when the foundations had appeared above the water the lower walls of the lower story were submerged twice a day, leaving heavy deposits of marine plants, shells, and seaweed. The workmen lived in huts upon a reef, to which they retired when the tide rose ; and thus they pushed on their labors, quarrying and squaring at one time, arranging and fixing at another. Their's was a masonry almost without mortar. The blocks were grooved and literally dovetailed together, the course being connected, as it were, by cogs, so that every part relied upon every other, the result being, as nearly as possible, an absolute cohesion. In spite of this happy issue the reporting architects would not recommend similar experiments in the future. Such works, they urge, are costly, and their success is uncertain. The day may come, too, they add, when for all this invention may be substituted structures of concrete, or of a cement which, in the course of a few hours, will change into the hardness and consistency of granite—a process, they inform us, which has already been resorted to in the construction of many of the minor French light-house towers—the martellos of the system. Of the higher class, indeed, some are built of other materials than stone—of iron, in fact, wrought and cast, such as stand along the less-frequented coasts, or on the shores of colonial territories with small financial resources. Thus, there was lately constructed at Paris a metallic light-house, 130 ft. in elevation, which was carried in pieces to New Caledonia, where it was set up, and now indicates the safest approach to the anchorage of Port de France. There is another of this class at Pontaillac, near Royau, and a third, subsidiary to the great historical light-house of Calais. But there are positions of this coast where it has been found impossible heitherto to maintain a permanent structure of any kind, and where nothing can be provided beyond a stationary life-boat, so to speak, anchored by cables of tremendous strength and surmounted by masts out of all proportion to their size, and bearing aloft a brilliant lantern. These, however, are devices with which French architects are by no means satisfied, since they affirm that, with adequate determination, a foundation can be discovered, whether on the land or beneath shallow sea, anywhere. In point of fact, they stigmatize them all as provisional, and will not in any way admit that light-house science has exhausted its resources merely because a few projectors have been baffled, and they signalize a variety of English triumphs in this direction which ought, in their opinion, to shame every one out of his apprehensions. There is not much, however, for France to be ashamed of in this respect. Along her shores upwards of 300 beacons are kindled every night for the guardianship of the navigator. It would be impossible to follow the commission in its tracing of their distribution ; but of the cheif structures—that is, of those whose rays are visible from a distance of from 18 to 25 miles—there are three in the channel, at Dunkirk, at Calais, and at cape Grisnez, which should always, in ordinary weather, be visible from one point or another of the British coast. The first obscures itself each alternate minute, the second sends a flash once in every three or four minutes, the third every 30 seconds, so that it is impossible to confuse or mistake them. In conjunction

with these are two of the second order —those of Gravellines and Walde—the one with a fixed white and the other with a fixed red flame. No seaway in the world is better lighted from the land. The peninsula of Brittany, beset by a swarm of shoals and islets, requires no fewer than 17 light-houses, while from the mouth of the Garonne to the Spanish frontier there are only three, so rarely interrupted are those dismal waters. This is a circumstance due to the accidents of population and commerce. Another, of a different kind, though equally interesting, applies to the sea-board along the Mediterranean. There the atmosphere is usually, even by night, so transparent, and the dangers are so few, that seven light-houses only, of the first order, with a small number of inferior beacons, suffice for that great stretch of coast. A similar remark is applicable to the Corsican and to the Algerian waters. The commission, therefore, deprecates any profuse expenditure upon such works in the interest of sea-boards thus naturally protected. It is not to be supposed, because this notice of the report is necessarily too brief to include even a summary of its whole contents, that the collateral topics connected with this great object are neglected. On the contrary, specific attention is devoted to light-house lamps, from the Argand to the Dioptric, and downwards; those employed by the French, to this day, being almost universally fed with what is known as Colza—or, in plain language, cabbage—oil, each light fed with this, costing on an average £300 a year. But the positive construction and working of the French Pharos appeared nearer to our purpose. With regard to the latter, it is now, in general, effected by means of a small steam-engine, though numberless experiments are still being tried in association with this active power. The steam-engine, moreover, affords another advantage. In the event of weather too dense to admit of the most brilliant flashes being visible at any distance great enough to be of service to the mariner, it can be used to blow the fog-horn with an effect that can be heard for miles, however heavy the atmosphere, and whatever may be the influences interrupting light or sound. Altogether, when the Ministry of Marine think fit to publish this newest of Parisian Blue-books, it will be found to contain a great abundance and variety of information upon a subject of distinct importance, and particularly with reference to the mechanism and management of light-houses. The interest of the matter is enhanced by the proposal of an international emulation, in which the inventors of light-house lamps and lantern-houses shall compete. But this idea has taken no definite form as yet."

We append some abstracts from Maj. Elliot's record of his tour along the English and Irish coasts :

We passed the Mucking light-house, situated in the Thames, below Gravesend, and the Maplin Sand light-house, off the mouth of that river. Both of these are screw-pile structures ; the latter was, I believe, the second of that kind in the world, having been lighted in 1841, and was one of the earliest applications of that useful invention of Mitchell, of which we have many examples, there being more than fifty light-houses built on that plan in the United States.

It may be mentioned here that the first screw-pile light-house was built at the mouth of the River Wyre, on the northwest coast of England, two or three years before the light-house on the Maplin Sand. The screws were three feet in diameter, the piles five inches ; and above the ground, instead of iron, as at Maplin, wooden columns were used. This light-house was destroyed in 1870.

The Maplin Sand Light-house (a view of which is shown) is a hexagonal structure, with one central and eight exterior piles. The piles were driven vertically, but above the water-line they bent toward the center and incline in a pyramidal form to the lantern-floor. The screws are four feet in diameter, the piles five inches, and they support cast-iron columns 12 inches in diameter. The columns are very strongly braced, and the structure had an appearance of great strength.

We stopped at the Gunfleet Light-house, situated on a sand of that name, north of the mouth of the Thames, and thirty-one miles from the Nore Light-ship. It is exposed to the full force of the North Sea.

There are one central and six exterior piles supporting columns of about 12 inches in diameter, strongly braced.

The sockets for the columns are not cast in one with the sockets for the braces, but the latter are bolted against the face of the piles by tap-bolts.

Unlike Maplin Sand Light-house, the

MAPLIN SAND LIGHT-HOUSE.

piles were not driven vertically, and are inclined from the bottom to the top in the form of a pyramid. The piles, braces, and sockets are of a very massive

character, and give an appearance of great durability and of the strength which the sight demands.

The dwelling for the keepers (below the lantern-floor) is but one story in height, and is smaller and less convenient than in similar structures in the United States. The sides and roof are made of corrugated iron with wrought-iron angle plates. Below the floor of the dwelling additional space is furnished by placing a store room in an inverted pyramid, to which access is had by a ladder from the gallery. The dwelling is divided into a living room (also used as a kitchen), a bed room and an oil room. It was stated that the sea rarely rises to the bottom of the house, and the object of the peculiar form given was to allow the wind and spray to be warded off without imparting shocks to the structure. I should judge the device to be one of questionable utility, and that but little more expense would have been incurred by raising the building a few feet higher and placing another full story for the accommodation of the keepers.

There are two keepers, one less than we would have in the United States, and it will be observed throughout this report that the British lights are maintained by a less number of keepers for each than for the same order of light in our service.

The lantern, which is large and commodious, contains a revolving catoptric apparatus composed of fifteen reflectors and Argand burners in sets of five, placed on a frame of three sides, and this being a red light, panes of red glass, in frames hung on hinges, were placed in front of each reflector. This structure seems admirably adapted to the locality, and I should think the question of replacing by similar structures some of the great number of light-ships which mark the channels through the shoals obstructing navigation on the east coast of England, would have attracted attention, and there are probably some special reasons why it has not been done.

While the first cost of a screw pile light-house in an exposed locality is greater than that of a light-ship, the cost of maintenance as well as of repairs is much less; and besides, the danger which sometimes occurs of light-ships being dragged from their stations and leading vessels into the very dangers from which they are intended to warn them, is avoided.

These considerations have induced us to replace our light-ships by screw pile light-houses except in the case of shifting shoals like those off the Island of Nantucket.

The Outer Farne or Longstone Light-house is, with the exception of a small pier light at Berwick, at the mouth of the Tweed, the most northern of the North Sea lights of England, and is in view of the light on St. Abb's Head, the first of the Scottish lights.

It is a rock light-house of the peculiar construction shown in the Plate, the tower and dwellings being surrounded by high walls to protect them from the sea, which frequently rolls with great violence over the rock, which is long and narrow.

A new first order revolving lens, made by Chance Brothers & Co., has recently been placed in the tower, and the entire station has been repaired and refitted, the mechanics being still at work at the time of my visit.

While at Coquet Island I saw this light very distinctly from the deck of the Vestal, say 10 feet above the sea, at a distance of twenty miles, which was remarkable, as the focal plane is but 85 feet above the sea.

There is only the ordinary number of keepers (two) at this station, but they are supplied with provisions from the mainland and but rarely leave the rock.

This light-house is interesting as having been the home of Grace Darling, the daughter of a former keeper, and to whom owed their rescue the nine out of the sixty-three who were on the Forfarshire when she struck the "Hawker Rock," near the Longstone, on the 5th of September, 1838.

The keepers had much pride in showing us the bed-closet occupied by the heroine and the window through which she first saw the wreck. A beautiful tomb is erected in her memory, at Bamborough Castle, near by on the mainland.

Wicklow Head, on the western side of Saint George's Channel, south of Dublin, we reached partly by rail and partly by "jaunting-car," a two-wheeled

vehicle, which is the common conveyance of the country.

The gas-house, containing the furnaces and retorts, the gas-holder and other buildings, are ingeniously disposed on the face of a high cliff, and occupy but little space, as shown by the frontispiece.

This is a first order intermittent light, the lens-apparatus being that of an ordinary fixed light. The gas is let on and

THE LONGSTONE LIGHT-HOUSE.

shut off by an automatic arrangement which allows ten seconds of light and three seconds of darkness. This arrangement does not cut the gas entirely off, and each jet during the three seconds' eclipse shows a tiny blue flame, which, while it produces no illumination of the lenticular apparatus and can scarcely be

detected in the daylight, is still sufficient to light the main body of gas when the supply is turned on.

To guard against all danger of total extinguishment of the light by gusts of wind through the ventilators or door of the lantern, each jet is surrounded by a small pipe called the "by-pass," the top of which, being at a level with the tip of the jet, is pierced by several minute holes through which gas is supplied from a pipe quite independent of the automatic cut-off; thus protected, these little jets of flame burn from the moment of lighting at sunset to that of extinguishing at sunrise, and it is impossible even if the "cut-off" or a gust of wind should completely extinguish the main flame that the burner should not be lighted at regular intervals of thirteen seconds.

The two keepers at Wicklow Head agreed with those at Howth Baily in saying that the gas gives very much less trouble than the oil light.

Mr. Wigham has invented a gas gun, to be used as a fog signal at stations illuminated by gas; and I had an opportunity of testing it, both at the manufactory in Dublin and at Howth Baily light-station. Captain Hawes kindly directed that the gun should be fired during our observation of the triform-light from Kingstown, so that, at a distance of six miles, I could judge of its efficiency as a signal.

The gun is simply a tube of iron connected with the gasholder by a half inch pipe; in fact, in these experiments the guns were nothing more than pieces of ordinary gas or water pipe of different diameters. The charge of the gun is a mixture of oxygen, coal gas and common air, one-fourth of the mixture being common air and the remainder composed of equal volumes of oxygen and ordinary illuminating gas.

The proper quantities of the gases are allowed to flow from their respective reservoirs into a holder, and the mixture is thence transferred to the closed end of the pipe or breech of the "gun," the flow being regulated by a stop-cock. The mixture is lighter than common air, and when it fills the feed-pipe and gun, the latter being lower than the source of supply, it will remain charged or full until fired, which may be done by touching a match to an orifice at any point of the connecting-pipe desired, taking care that communication with the holder is closed by the stop-cock.

The product of the explosion is carbonic acid gas and water, and, as the latter would rapidly fill any part of the feed-pipe which might be lower than the gun, it would probably be a fatal objection to the use of the invention which immediately suggests itself, viz., its application as a fog signal on outlying rocks difficult to approach or nearly submerged. The defect is all the more to be regretted, as it is at precisely these points that fog-signals are most needed and the erection of other kinds are impracticable.

At Mr. Wigham's extensive works at Dublin the feed-pipe was several hundred feet long.

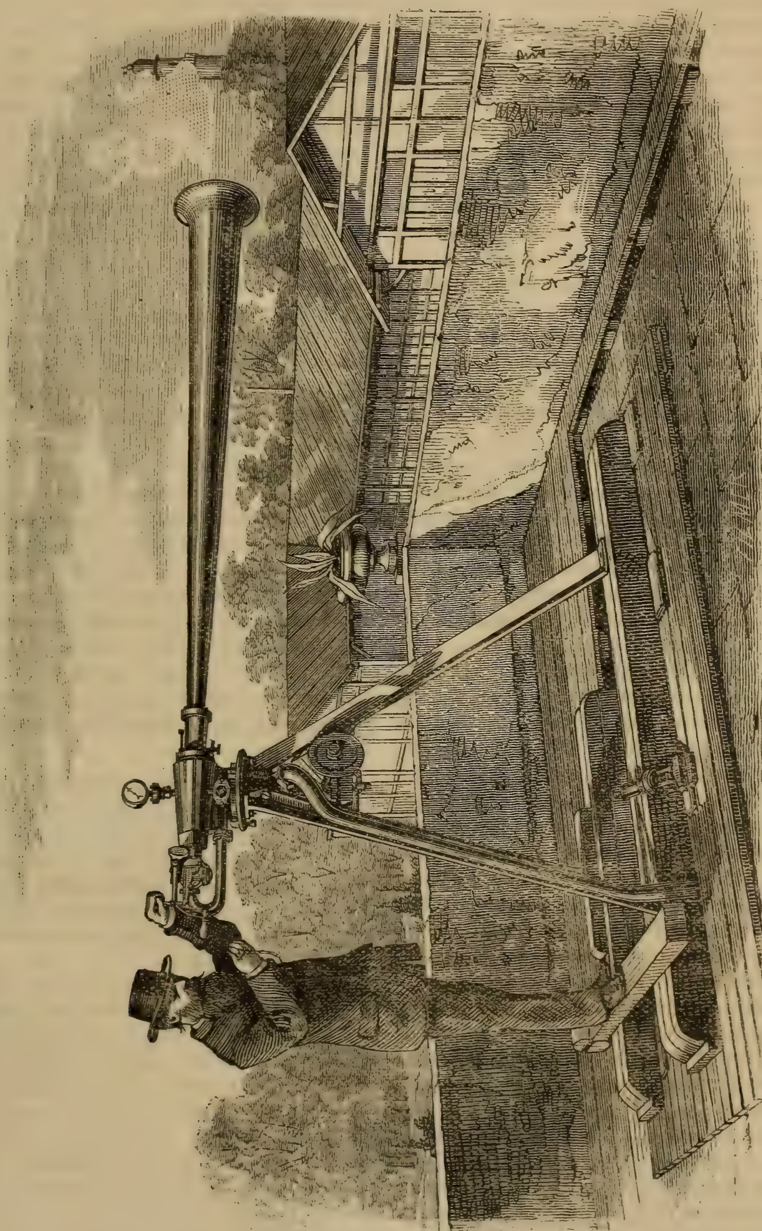
The use of the gun at any gas-light station would be extremely simple, and the keeper need not go to the gun itself, but could easily fire it from his watch-room at the required intervals. I do not know that the experiment has even been tried, but it will readily be seen that by using the electric spark the service of the gun might be made still easier, for a system of clock-work connected with a battery could be easily devised by which an electric circuit could be formed and a spark produced at any desired interval, and thus the gun be fired without any attention on the part of the keeper except what might be required to keep the apparatus in order.

At Howth Baily the guns were twelve inches in diameter and from six to nine feet long. The latter were duplicated, and consisted of two connected pipes, fired simultaneously. Near at hand the reports seemed loud and clear, but when heard from Kingstown a high wind prevailed over Dublin Bay, and I was disappointed in the results. It is true that the distance was six miles, and a comparison with other signals would have been more satisfactory, but I fancied that the 18-pounder fog-signal gun at North Stack, on the other side of the channel, would have been more distinctly heard under the same circumstances.

The flash from this gun is said to illuminate fog much better than that from a gunpowder-gun.

I have no doubt of the utility of the

invention for fog signals at stations illuminated by gas, if the very great expense attending the manufacture of oxygen can be overcome; and, as Professor Tyndall is now charged by the Board of Trade with the conduct of a complete series of experiments with the gas-gun, it is to be hoped that the inventive genius of Mr. Wigham will overcome all objections to which it may now be subject.



THE AUSTRIAN FOG TRUMPET, (NEBELHORN.)

In concluding my observations on Irish lights I must express sincere thanks to the commissioners and to Captain Hawes, the very intelligent inspector of lights, as well as to Mr. Lees, the secre-

tary of the board, and to Mr. Wigham, for the pleasure and instruction I derived during my limited sojourn in Ireland.

Of Fog-Signals the following account is taken from a later portion of the report accompanying the plate, which is copied from the photograph sent by Mr. Jay, represents the fog-trumpet as I saw it at the exhibition at Vienna, and the following is a translation from the Italian of the description which accompanied it:

"Since the introduction of acoustic signals, used in America as well as in Europe to mark dangerous points on the coast in foggy weather, it has become desirable to have a more perfect instrument, an apparatus that can be used not only at light-stations in foggy weather and snow-storms, but also on board of ships, especially on steamers, not only as an alarm but as a signal for correspondence.

"This object has been fully accomplished by the invention of Giovanni Amadi, of the Technical Institute of Trieste. His trumpet was exhibited at the universal exposition at Vienna, and was awarded a medal of merit.

"This apparatus, which consists of a trumpet, formerly operated by compressed air, but now directly by steam, is provided with an automatic distributing steam-valve, and with a special valve with finger-board (operating keys) so as to produce sounds at will.

"The instrument has a most extraordinary power in proportion to its dimensions and to the pressure of steam required to produce the vibrations ; it can be put up either directly over the boiler or separately, and connected with it by a pipe, and it can be turned to any part of the horizon.

"In addition to its use as a fog-signal on shore, it may be applied on board of steamers of whatever steam-power, and is especially advantageous on board of men-of-war.

"By means of the finger-board, one is enabled to give long and short sounds at will with great accuracy, and communications may be made at night, in fog, or in snow-storms, by means of an alphabetic formula similar to that used in telegraphy.

"The trumpet is operated by a steam-boiler of eight horse-power and a pressure of twenty-five pounds per square inch.

"The boiler is more than sufficient to produce thirty blasts in thirty seconds, which are audible at a distance of fifteen nautical miles in clear weather.

"Connected with the boiler is a small machine, which operates the automatic distributing steam-valve and can be so regulated that the different intervals in the sounds distinguish the different stations where trumpets are used.

"In the Technical Institute at Trieste, where this trumpet was constructed, it was very particularly tested, and the government officers at Trieste testified that the sounds were plainly audible at a distance of fifteen miles, the height of the trumpet being thirty English feet above the sea ; also that when operated with the finger-board, the signals, according to Morse's method, could be plainly distinguished at a distance of six nautical miles.

"The Austrian goverment purchased this trumpet to operate it on Point Salvore, Istria, after trial of a smaller one of the same kind (audible five miles) near the light-house at Trieste.

"A third trumpet, with a steam generator of two horse-power, and audible eight miles, has also been ordered and finished, and will be put in operation on board of the light-ship anchored at Grado."

In the matter of specific character of signals at different stations, the following extract from a late paper before the British Association, by J. Hopkinson, D.Sc., M.A., and published in the *Nautical Magazine*, contains the latest suggestions for improvement :

The increase in the number of light-houses has caused a difficulty in insuring that they shall not be confounded with each other. The existence of this difficulty is apparent from the defects of various expedients to which light-house engineers have reluctantly resorted to obtain necessary distinctions. In the most favorable circumstances, red glass absorbs nearly two-thirds of the light which would otherwise benefit the sailor. The use of color is thus an extravagant expedient, for an equally powerful white light could be produced with a much smaller consumption of oil. Still it has

been frequently necessary to employ red glass even in revolving lights. It must be a strong necessity which makes light-house boards consent to have the brightness of their lights so heavily taxed. The first French Light-house Commission definitely excluded colored lights from their scheme, but even France has had to give way. In an ideal scheme of lighting a coast, color would only be used for making particular directions from the light-house, as at Orme's Head, the Longships, and other places, but we should have no lights showing red, or alternately red and white, to all points of the compass. Another distinction which has found a great deal of favor is open, I think, to even graver objections than the one of color—the fixed and flashing light Here we have a light of the power of a fixed light during a greater portion of the time, but flashing out at stated intervals with the brightness of a revolving light. The essential *characteristic* of these lights lies in the combination of continuous light of a certain intensity, with flashes of a very much greater intensity. There must undoubtedly be circumstances of weather and distance in which the flashes alone can be seen, and the effect be similar to that of a revolving light, and be only distinguishable from it by the usually greater interval between the flashes. It is true the local knowledge of the seaman may remove the doubt, but on this the light-house engineer has no right to rely, and the fixed and flashing light remains open to the objection that in fair weather it appears as it is advertised to be, in foul it may simulate a revolving light, and may in extreme circumstances cause mistake and consequent disaster. The cost is that of a revolving light, but without its advantages. It is difficult to see why the ordinary intermittent light was not adopted instead of this dangerous combination.

Light-house optical apparatus may be broadly divided into two classes, the fixed, in which the light being condensed in altitude only, is sent simultaneously in all directions to the sea horizon; and the revolving, in which the lenses condense the rays in azimuth also, and as the apparatus revolves, cast powerful beams on the eye of the mariner at stated intervals, total darkness, with the exception of dim light scattered in the lantern, separating the beams of light. The former is open to one or two objections, the importance of which increases every year. There are no means of distinguishing one fixed light of the usual kind from another : as the demand for more frequent lights along the coast increases, this limits the use of fixed lights. On a very dark night, when the hulls and masts of vessels cannot be seen, there is some difficulty in distinguishing a distant fixed light from a nearer ship light or riding light. It has been urged as an objection to the now absolutely unnecessary increase in the power of ship lights, that they would thereby be liable to be confounded with light-houses. When visiting the Dungeness Light, I had the opportunity of observing the magnificent electric lights of the South Foreland, distant twenty-two miles, behind the lights of vessels riding at anchor near to, and I felt that I could not instantly and certainly distinguish one from the other. Doubtless, the experienced eye of a seaman would have instantly identified the light-houses, but perhaps the judgment of a landsman on the beach in a dark but clear night may be taken as a measure of that of a seaman on board ship in rough and rainy weather. For harbors, the fixed light is adopted in nine cases out of ten, and here an additional cause of trouble may arise to those unacquainted with the locality. Before the introduction of gas the harbor light was alone, and therefore unmistakeable; now it is sometimes almost lost amongst the gas lamps which illuminate the quay. Sir William Thomson has proposed to obviate these difficulties, whilst retaining the advantages of the fixed light, by improving the intermittent light, of which we have existing examples in Point Lynas, Anglesea, and other places, and diversifying it so that it might be applied to any or all of the fixed lights existing or to be constructed. His scheme may be best explained by reference to the light on the Holywood Bank, Belfast, which has been altered in accordance with his recommendations. This light is now distinguished by two short eclipses and one long, grouped together. The eclipses are produced by opaque shades revolv-

ing round the usual dioptric apparatus. The effect on the eye is as follows: bright 6½ seconds, dark ½ second, bright ½ second, dark, ½ second, bright ½ second, dark 1½ seconds, then again bright for 6½ seconds, the phenomenon repeating itself with a total period of 10 seconds. The three eclipses are easily described, and are instantly identified almost without thought. It is easy to see that the plan is as fertile as it is simple, and that it could furnish as many distinctions of fixed lights as can ever be wanted. Some difficulty was at first anticipated as to the possibility of adopting Sir William Thomson's proposal in the case of that important class of fixed lights in which certain bearings are marked by colored light, the colored light being made of equal power with the white by utilizing light which would otherwise be wasted on the land. But through these difficulties the way is now clear, and it may be safely asserted that there is no mechanical or optical difficulty in producing Sir William Thomson's eclipses in any case to which our light-house boards may think it expedient to apply them.

But revolving lights, in addition to their distinctiveness, have a recommendation in their great power. The use of red in revolving lights sufficiently proves that there is need for increasing the number of variations in this class. To meet this need I have designed forms of apparatus which give, instead of a *single* flash at stated intervals of 30 or 60 seconds, *two*, *three*, or, if required, *four* flashes in rapid succession, forming a group recurring at suitable intervals, such lights would naturally be named *double*, or *triple*-flash lights, or revolving lights with *double* or *triple*-flashes at intervals of 30 or 60 seconds, in contradistinction to the old revolving light, which would be distinguished as having a single flash. The apparatus is perfectly simple, and costs very little more than the ordinary revolving light. In the usual eight-sided light the rays are condensed into eight beams, the axis of which are at equal intervals of 45°. The double-flash light has twelve sides, giving twelve beams of light, but these are not spaced at equal intervals, but are grouped together in pairs, the axis of the lenses being alternately at intervals of 15° and 45°, if, then, the apparatus revolve in six minutes, as will be the case at the Little Basses, we shall have a powerful beam of light thrown to the eye, then a second of equal power, the two occupying about 22 seconds, then 38 seconds of darkness, to be followed by another group of beams of light. The triple-flash light is very similar, but has fifteen sides, five groups of three each.

There are several points of view from which the efficiency of a light may be judged, and it may be well to compare the new forms with the old in different aspects.

It is desirable that with a given consumption of oil the light should be as powerful as possible, or that no more oil than is absolutely necessary should be used to produce a light of a certain intensity. On the other hand, it is well that the light shall not be too long invisible, in fact, that it shall be seen for as many seconds as possible in each minute. These two conditions are exactly opposed, for as we condense more light into each beam by increasing the size of our lenses, we diminish the duration of brightness in comparison with that of eclipse. With a given illuminant, we may take as a measure of brightness sixty divided by the number of seconds the light is visible in each minute. Thus each panel of an eight-sided revolving light condenses light which would be dispersed over 45° of the horizon into about 4½°, it can thus be only seen during six seconds in every minute, and its power is ten times that of the corresponding fixed light. In Sir William Thomson's eclipsing system, the oscillations are so short that the light may be considered as continuously visible; they will also have the same power as the fixed light from which they are formed. They are in fact fixed lights furnished with distinguishing characters. The double and triple-flash lights on the other hand, are modified revolving lights. Let us compare the eight-sided revolving light, giving a flash every minute, with the double and triple-flash lights, giving respectively a group of two and three flashes every minute. The eight-sided light if it were white, would have a power of ten, taking the corresponding

fixed light as unity, but nearly two-thirds of this light is intercepted to make the light red. Its power will then be represented by a little less than four. The flash will also last but six seconds, and this will be the whole time for taking the bearing of the light until fifty-four more seconds have elapsed. In a double-flash light we have 30° condensed into $4\frac{1}{2}°$, thus the intensity will be represented by $6\frac{2}{3}$, whilst the distribution of the light and darkness will be very favorable, the individual flashes will last $4\frac{1}{2}$ seconds, they will be separated by an eclipse of $10\frac{1}{2}$ seconds, and there will be a long interval of forty seconds between the groups. The two flashes will be almost as convenient for taking a bearing as a continuous light lasting twenty seconds. Turning to the triple-flash light, we have a power of $5\frac{1}{3}$, whilst the individual flashes will last nearly four seconds, and the group will occupy twenty-four seconds, giving an admirable opportunity of determining the direction of the light with such accuracy as the circumstances admit of. It may be said, generally, that the double and triple-flash lights rank next to the eight-sided revolving light in power, when the flashes of the latter are undimmed by the use of color, whilst they rank before all other revolving lights in the facilities they afford the mariner of making an accurate estimate of his position.

Perhaps the most important question which can be asked, regarding any new distinctive light which may be proposed is, Is it perfectly simple and easy to comprehend? Can it under any circumstances be mistaken for some other form of light? At first sight it would appear that both plans here described are opened to the charge of complication; but a moment's consideration shows that this is not the case. It is easier to recognize a group of two or three flashes from a single one, or to distinguish between groups of three eclipses—say, "short, long, short," from "short, short, long," than to ascertain certainly the period of a revolving light. Again, it may be urged as an objection to groups of flashes that some circumstances may cause the observer to miss one flash in the group and mistake a double for a single, or a triple for a double-flash light. Again, I appeal to time-honored experience. It is conceivable that by the obliteration of a flash a half-minute light may be taken for one having a double period. If such a mistake occurred, it would be longer before it could be rectified than in the case of the double-flash light; but I am not aware that any such inconvenience is actually felt.

The advantage lies wholly with the new lights; a group of three flashes or eclipses would be recognized without hesitation by a savage who was utterly ignorant of any means of measuring time, whilst the difference between thirty seconds and a minute would be without meaning to him. There is no complaint, nor cause for complaint, of the best revolving lights on the score of simplicity, and certainly still less will there be in the new combination.

It is worthy of notice that, if a coast were lit on a system based on a use of grouped flashes, or grouped eclipses, with the appearance of the light could be made to correspond the blasts of the fog-horn; a group of three flashes, at intervals of thirty seconds, would naturally be used in conjunction with a fog-signal sounded three times in succession at the same interval.

Maj. Elliot's experience in connection with the trials of fog-signals at Dover is thus related:

On the 19th of May I proceeded to Dover, to be present at the commencement of an extensive series of fog-signal experiments, to be undertaken by the Trinity House, under the supervision of their scientific adviser, Professor Tyndall.

There were present on this occasion, besides Professor Tyndall, several of the Elder Brethren, the Engineer of the Trinity House, a representative from the Board of Trade, and the Inspector of Irish lights.

The experimenters divided themselves into two parties, and embarked on two steam-yachts, for the purpose of practically testing the sounds while afloat.

The limited time at my disposal did not allow me the pleasure of accepting an invitation to join them, and I had only an opportunity of observing the machines themselves at the experimental station at South Foreland. This I did be-

fore inspecting the South Foreland light-houses to which I at once proceeded.

There were two sets of signals used; one placed on the summit of the cliff near the engine-house belonging to the light-station, at an elevation of 275 feet above the sea; the other near the foot of the cliff, at an elevation of 40 feet, and near the bottom of an old shaft, by which it was reached from the upper station.

The machines used were steam whistles, air whistles and fog trumpets. The trumpets and the air whistles were connected with two air chambers, supplied with air by pumps driven by the engine used for the electric lights.

An Ericsson engine was at the station, but was not used.

The steam whistles were supplied by a twenty horse-power upright engine.

The trumpets were shaped like those used in our own service. The steam whistles, with a diameter of 12 inches, had a height of 14 inches, the space between the lip and the disk being $1\frac{3}{4}$ inches. The air whistles, with a diameter of 6 inches, were $9\frac{1}{2}$ inches high, the lips being placed $1\frac{1}{2}$ inches from the disks.

The steam whistles were blown under a pressure of 64 pounds; the air trumpets and whistles under a pressure of 18 pounds. Behind these latter were reflectors about 12 by 15 feet, slightly curved toward the land.

The day was stormy, there being a high wind from the eastward accompanied by rain, and the Strait of Dover was pretty rough, but on the whole the weather was favorable for the purpose. The two parties continued afloat all day, and the signals were sounded until dark.

On shore, so near the signals, and while inspecting the light-houses, I could not determine in regard to the qualities of the different sounds as well as could those on board the yachts, but, so far as I could judge, the air whistles and trumpets were decidedly superior to the steam (12-inch) whistles. The note of the latter was much more shrill than that found by us to best serve the purpose for which this instrument is designed, and the condensation of the steam, and consequent drip of water were so great, I was convinced, as to greatly impair the vibration.

The results of the trial of the 12-inch steam whistle were from some cause much less satisfactory than in our experiments at Portland, and at our light stations, the sound produced being certainly no louder than that of the 6-inch air whistle.

On the return of the experimental parties in the evening, there was a general expression of disappointment in regard to all the signals.

It was stated that the yachts ran outside the limits of sound at comparatively short distances; that the air trumpets and whistles were heard much farther than the steam whistles, while a gun fired at Dover Castle was heard at much greater distance than any of the signals at the station.

The yachts were out in the channel occupying various positions in relation to the wind, and the signals were regularly sounded according to a programme previously arranged.

The experiments, in which were afterward included one of our own whistles and sirens, were to be continued for some months. Following will be found a list of the printed questions to be considered and answered by the experimenters:

"SOUTH FORELAND FOG-SIGNAL EXPERIMENTS—QUESTIONS PROPOSED TO BE DETERMINED.

"First. What is the most efficient height above the sea surface for the signals?

"Second. What are the comparative values of air and steam for sounding whistles and horns?

"Third. Which is the more efficient instrument—whistle or horn?

"Fourth. What is the proper pressure, having regard to efficiency and economy, at which air or steam should be employed for whistles or horns?

"Fifth. What is the relative range of the same whistle or horn with various pressures of steam or air?

"Sixth. What is the relative range of long and short blasts from the same instrument, and what is the minimum duration of the blasts of maximum efficiency?

"Seventh. What is the most efficient note for a fog-signal?

"Eighth. What is the relative range

of the highest and lowest notes of the same instrument?

"Ninth. What is the relative range of one and two whistles or horns of the same power?

"Tenth. What is the relative range of the horn in the direction of its axis, and at 45° and 90° respectively from the direction of its axis?

"Eleventh. Is the horn used with maximum efficiency by always keeping it pointed to windward, by using more than one horn and distributing the sound over the phonic arcs or by rotating one horn?

"Twelfth. Is any appreciable advantage gained by using reflectors in conjunction with whistles or horns; and, if so, what shape is preferable?

"Thirteenth. What horse-power is required to sound the most efficient signal (whistle or trumpet) for giving an effective range (of two miles) in fog and against wind at force 9 of the Beaufort scale?

"Fourteenth. How is the propagation and distribution of sound affected by different atmospheric conditions?"

It has been found by General Duane, of the Corps of Engineers United States Army, and light-house engineer of the New England coast, in his experiments made to determine the best form of boilers for steam fog-signals, that, as the steam used is at a high pressure, and is drawn off at intervals, and there is a consequent tendency to foam and to throw out water with the steam, a horizontal tubular boiler (locomotive) with rather more than one-half of the interior space allowed for steam-room, is best adapted for the purpose.

The steam-dome must be very large and be surmounted by a steam-pipe 12 inches in diameter. Both dome and pipe were first made small, and were gradually enlarged until no difficulty with regard to foaming remained.

The steam should be drawn off at a point 10 feet above the water-level in the boiler.

The main points, therefore, to be observed in regard to the *boiler*, are to have plenty of steam-room and to draw the steam from a point high above the water-level.

In regard to the *bell of the whistle*, the best results have been obtained by making the diameter two-thirds of its length, and the "set" of the bell, *i. e.*, the vertical distance of the lower edge above the cup, from one-fourth to one-third of the diameter for a pressure of steam of from 50 to 60 pounds.

These conditions were not fulfilled in the Dover experiments at the time of my visit, and I have no doubt that this accounts is some measure for the disappointing results of the trials with the steam-whistle.

ON THE PNEUMATIC TRANSMISSION OF TELEGRAMS.*

From "The Engineer."

There are twenty-four pneumatic tubes in London, of an aggregate length of seventeen miles 1,160 yards, four tubes in Liverpool, three in Dublin, five in Manchester, three in Birmingham, and one in Glasgow. When the number of tubes became large, it was fonnd necessary to simplify the valves and sluices, rendering them less automatic, but easier to keep in order, than the earlier apparatus. Lead was preferred to iron as the material for the tubes. An experience of twenty-one years had shown that with felt message holders, or carriers, there was no abrasion of the metal, which became highly polished, and that the tubes were practically air-tight, the exhaustion in one, 1,289 yards in length, occupying thirteen minutes in falling from 17.25 in. of mercury to atmospheric pressure, including the leakage from the valves. Iron had been used for two tubes, each 2,610 yards long, but it was found to rust rapidly, and to wear out the carriers. In the Paris system the iron tubes did not rust, and it was suggested that the difference was due to the

* A paper read before the Institution of Civil Engineers by R. S. Culley.

air in Paris being carefully cooled by water, and to the friction of the heavy carriers of iron covered with leather; while the air in London was used warm from the pumps, and the carriers are made as light as possible. The diameter adopted for the tubes is $2\frac{1}{4}$ in., as being large enough to carry the traffic with sufficient speed, and not so large as to require a costly volume of air. The carriers are cylindrical boxes of guttapercha, covered with shrunk drugget; their weight was $2\frac{3}{8}$ ounces. The traffic is regulated by electric signals. Stoppages are rare, and are cleared by filling the tubes with water and applying pressure. It has never been necessary to open a lead tube, except in cases of bad construction, or of external injury caused by workmen.

On the Continent, with perhaps an exception as regarded the Paris Bourse, trains of carriers were run at fixed times, in Paris every quarter of an hour; but in England a message was never delayed —speed was the first requisite, and carriers followed one another as rapidly as possible. An opinion expressed during a former discussion of the subject, that pneumatic was more costly than electric transmission, was shown to be erroneous; for the total expense of the former in London was barely two-thirds of the amount which would have been required to pay the salaries alone of the clerks needed under the latter, irrespective of the cost of wires and instruments.

Experiments showed that the speed of a carrier driven by compressed air was greater when the pressure was cut off after each transit; or, in other words, that there was a loss of speed when the air was kept constantly in motion. In the former case the carrier started into a comparative vacuum at atmospheric pressure; in the latter case into dense air; consequently the higher the pressure employed, the greater the difference in speed—with 14 lb. pressure the difference was 6 per cent. In working by vacuum a reverse result obtained. The experiments likewise demonstrated that the pressure fell to zero at the distant end and almost regularly with the length, but not quite so. With an initial pressure equal to 18 in. of mercury the pressure at the end of a tube 8454 ft. long was 9.75 in. instead of 9 in., and in every case there had been a higher pressure at intermediate points than that due to their position, when the fall of pressure was represented by a straight line. This result was attributed partly to the inertia of the air, partly to friction. The experiments also showed that when compressed air was admitted into a long tube, or the air was pumped out of it, a sensible time elapsed before the permanent condition of the air pressure was established. In a tube 5523ft. long this interval was forty-five seconds for the end next the air-pump, and about seventy-five seconds for the centre of the tube. The temperature of the air issuing from a tube was not lowered to an extent corresponding with its expansion in the tube, because it gained heat from the soil in London; but in Berlin, where the tubes were bedded in dry sand, the theoretical temperature was more nearly attained. Comparing a 3 in. tube with a $2\frac{1}{4}$ in. it was shown that more than double engine power gave only 16 per cent. higher speed in the larger tube, so that any increase of diameter above that actually necessary to carry the traffic in the required time was attended with unnecessary expenditure. Again, by doubling the pressure only 30 per cent. in time was saved, but thrice the engine power was needed. In two tubes, each 1000 yards long, one 3 in. and the other $2\frac{1}{4}$ in. in diameter, by working the larger with a pressure of 5 lb. and the smaller with one of 7 lb. the transit was made in nearly equal times, while the engine powers were 2.6 horse-power and 2.1 horse-power respectively. The smaller tube at the higher pressure was therefore the most economical. The tubes should in consequence be as small as possible. The relative economy of working by vacuum, or by pressure, was then considered, to determine at which end of a tube, required for traffic in one direction only, the engine should be placed. It would at first sight appear that vacuum would be less expensive, because there was less weight of air to move than when using pressure. But as the rarefied air gained heat from the tube as it passed along, the volume which must be removed by the pump was greater than it would otherwise be; so that practically the cost of the two systems was the same.

THE EFFECT OF DEAD SPACE IN WOOLF ENGINES.

By O. HOLLAUER.

Translated from Bulletin de la Soc. Indust. de Mullhouse.

II.

The internal heat increases continually during eighteen-twentieths of the course; on the other hand, the diagram itself gives as the work of the period of compression 77 k. × 81 m. ; hence

$$A\,F=\frac{77.81}{425}=0.18 \text{ c.}$$

a small amount of heat ; proving that almost the total increase of internal heat

$$U_n-U_0=46.53-41{,}47=5{,}06 \text{ c.}$$

is due to the action of the walls alone. These being up to this time warmer than the enclosed steam, evaporate the water that coats them. We shall see that the reverse might happen.

Finally, at eighteen-twentieths of the course the interior return stroke of the small slide closes up escape, and leaves between the two distributing chests 0,890 c. m. of steam at 0,993 k. pressure, and containing 15.7 per cent. of liquid water. The weight of this mixture is 0,0890 c. m. × 0,58271 = 0,0518 of steam, and $0{,}518 \text{ k.} \times \frac{0{,}0141 \text{ k.}}{0{,}0757 \text{ k.}} = 0{,}0097$ k. of water; making a total of 0,0615 k., of which the internal heat U = 0,0518 k. × 496,78 c. + 0,0615 k. × 99.37 c. = 31.84 c.

The rest of the 0,0898 in the small cylinder containing 0,0757 k. − 0,0518 k. = 0,0239 k. of steam, and 0,0141 k. − 0,0097 k. = 0,0044 k. of water ; total, 0,0283 k. of which the internal heat U = 46,53 c. − 31,84 c. = 14,69 c., continues to condense, and finally fills 0,0110 c. m. at a pressure of 2,016 k. In this condition the steam goes to mingle with that from the boiler. It contains 0,0110 c. m. × 1.1332 k. = 0,0125 k. of steam, and

$$0{,}0283 \text{ k.}-0{,}0125 \text{ k.}=0{,}0158 \text{ of water,}$$

or 55,53 per cent. Its internal heat

$$U=0{,}0125 \text{ k.}\times 480{,}24 \text{ c.}+0{,}0283 \text{ k.}\times 120{,}60 \text{ c.}=9{,}41 \text{ c.}$$

The mixture 0,0283 k. has lost during this period of compression in the interior of the small cylinder

$$U_0-U_n=14{,}69 \text{ c.}-9{,}41 \text{ c.}=5{,}28 \text{ c.} ;$$

the condensation is

$$55{,}83 \text{ per cent.}-15{,}70 \text{ per cent.}=40{,}13 \text{ per cent.}$$

This result of experiment, apparently paradoxical and contrary to the teaching of theory, is confirmed for the nineteen-twentieths remaining of the course, when the pressure 1,326 k. gives a weight of steam,

$$0{,}0259 \text{ k.}\times 0{,}76548 \text{ k.}=0{,}0198 \text{ k.} ;$$

and of water,

$$0{,}0283 \text{ k.}-0{,}0198 \text{ k.}=0{,}0085 \text{ k.,}$$

or 30 per cent., whose internal heat

$$U=0{,}0198 \text{ k.}\times 490{,}28 \text{ c.}+0{,}0283 \text{ k.}\times 107{,}70 \text{ c.}=12{,}75 \text{ c.}$$

an amount less than 14,69 c., which existed at the moment when the small slide cut off the escape.

So, notwithstanding the work of compression, the steam confined in the small cylinder condenses after the slide has separated it from that which fills the dead space between the two organs of distribution ; and the loss of heat is still due to the action of the walls which have been colder than the steam during this last period of rapid compression.

Now that we know the different weights, both of steam and water, which remain in the dead spaces and the consequent transformations, we can study the action that takes place in the same motor in case of compression or non-compression of steam in the dead spaces.

The weight of the mixture of steam and water, which leaves the boiler and traverses the cylinders at each stroke of the piston is

0,6956, being 0,6678 k. of steam and 0,0278 k. of water ; carrying with it a total heat

$$0.^{k}6678\ \beta+0.^{k}0278\,q=0{,}6678\times 651{,}17 \text{ c.}+0{,}078\times 147{,}83 \text{ c.}=438{,}96 \text{ c.}$$

This weight coming to the small cylin-

der is mixed with that which remains after compression, that is: 0,0125 k. of steam and 0,0158 of water at a pressure of 2,016 k., having a total heat

$$0.^{k}0125\ \beta + 0.^{k}0158\ q = 0{,}0125 \times 643{,}04 \text{ c.} + 0{,}0158 \times 120{,}60 \text{ c.} = 9{,}93 \text{ c.}$$

When the discharge from the small into the large cylinder opens, the steam again encounters in the dead space between the two slides, steam of weight 0,0518 k. and water of weight 0,0097 k. which have been left there after compression, containing a total heat

$$0.^{k}0518\ \beta + 0.^{k}0097\ q = 0{,}0518 \times 636{,}66 \text{ c.} + 0{,}0097 \times 99{,}37 \text{ c.} = 33{,}94 \text{ c.}$$

In the large cylinder we find the 0,0223 k. of steam, supposed dry, that remains after the escape into the condenser, of which the total heat is

$$0^{k}{,}0223\beta = 0{,}0223 \text{ k.} \times 623{,}67 \text{ c.} = 13{,}91 \text{ c.}$$

The values of the work per stroke were obtained by measuring the diagram curve surface with the planimeter.

With compression.

Work on the small piston,	10266 k. × m.
" " large "	12307 "
Work negative of counter pressure..............	3992 "
Total absolute work, F=	26565 k. × m.

Without compression.

Work on the small piston..	10565 k. × m.
" " large " ..	12475 "
Work on the negative of counter pressure........	3982 "
Total absolute work, F′=	27022 "

But to produce this work it was necessary to furnish of heat in the first case:

For the steam traversing the cylinders..................	438,96 c.
For that which traverses the jacket.....................	48,77 c.
Total C=	487,73 c.

Consumption for absolute work F=26565 per H. P. per hour

$$\frac{C \times 27000}{F} = 4957.2 \text{ c.}$$

and of dry saturated steam

$$\frac{4957.2}{651.17} = 7{,}6127 \text{ k.}$$

In the second case, supposing that there has not been compression in the dead spaces, there must be furnished besides the heat due to the steam which traverses the cylinders and the jacket 487,23 c.

There would be

In the dead space of the small cylinder..................	9,23 c.
In the space between the slides.	33,94
In the large cylinder..........	13,91
Total C′=	545,51 c.

Consumed to produce an absolute work F′=27022 k. × m., or per H. P. hourly,

$$\frac{C' \times 270000}{F'} = 5450{,}6 \text{ c.}$$

and of dry saturated steam,

$$\frac{5450{,}6}{651{,}17} = 8{,}3705 \text{ k.}$$

If then this engine had worked without compression it would have consumed at least 9,95 per cent. more than with compression; yet this compression is not pushed very far, and is easily attained in practice by proper management of the slides.

ENGINES WITH A SINGLE CYLINDER.

The analysis of this kind of motors with regard to dead space, if not impossible, is difficult.

Suppose that discharge into the condenser is stopped at four-fifths of the stroke. From this time there is confined in the cylinder undergoing compression during one-fifth of the stroke, a certain weight of mixed steam and water.

We say a mixture; for this steam is moist at the moment of closing the slide; examination having shown (even in the case of engines with steam jackets) that at the end of cut off there still remains 10 to 15 per cent. of water, mostly upon the walls; that during the discharge into the condenser a part, not all, of this water evaporates to give place to the cooling by the condenser.

In the Woolf engine during the period of expansion the *known* weight of mixture is between the two pistons; so that its constituents may be evaluated for

each point of the course. At the moment when the large slide cuts off communication with the small cylinder causing compression, the pressure indicated on the diagram gives the density and the weight of the volume of dry saturated steam, the residue being water.

This is not the case with single cylinder engines, in which all the steam compressed has been in direct communication with the condenser. A part of the 15 per cent. of water which it holds at the end of the expansion is evaporated upon the walls; the residue passes to the condenser in the condition of water; but how much remains in the cylinder at the moment when the slide has just closed?

Diagrams taken with Watt's indicator may, as with Woolf's engine, give the weight of dry saturated steam corresponding to the pressures at various points of the stroke. If the weights diminish we may affirm that there is condensation during compression; but in the contrary case, there may also have been some evaporation, which superheats the steam if little water remains in the cylinder. In either case one or the other of the phenomena must have taken place; for it is indispensable to know the weight of water remaining in the cylinders at the moment of closing in order to determine the internal heat of the mixture, the only value which determines of the transformation of the entire mass.

As soon as the slide opens the escape into the condenser, the steam is precipitated into it, and there immediately ensues upon the walls of the cylinder a very rapid evaporation of the coat of water which covers them. This phenomenon, identical with that observed in steam generators where a more rapid evaporation takes place every time that the motor uses a certain quantity of steam, carries along a quantity of water. We, therefore, naturally employ Hirn's calorimetric method, which has furnished us with satisfactory results when applied to steam generators.

But the process differs with the two kinds of engines; one in which the steam escapes freely into the air; the other, in which it passes into the cylinder. In the first case, the difficulty is no greater than when we operate upon the boilers themselves; provided that the pressure in the escape pipe is sufficient to cause discharge into the calorimeter. Otherwise we have recourse to a modification. At the extremity of the worm, a copper reservoir is soldered of about a litre capacity, in which a vacuum is made by introducing 250 grammes of water, and bringing to boiling point, so that the air is expelled. It is then cooled, when the stop-cock has been closed. The calorimeter being mounted, the reservoir and the worm are plunged into the cold water and the whole is weighed. Then the apparatus is brought near the escape pipe and filled, and the steam is allowed to flow slowly in and condense. When the water of the calorimeter is sufficiently heated, the stop-cock must be closed and the apparatus detached so as to weigh again, which gives the weight of condensed steam.

The initial and final temperatures of the cold water as well as the pressure are registered; consequently the temperature of the escape steam in the cylinder. We have then all the elements necessary to determine the amount of water carried by the steam, which is in some cases quite considerable.

The method employed for condensing engines is an application of a general method by Hirn (*Bulletin*, Oct., 1869). We give the results of two experiments made by us with Hirn upon an engine with and without superheating. The steam consumed was directly measured during an entire day; as was the water of condensation and its heat.

ENGINE WORKING WITH SUPERHEATED AT 231°; 143,78 IND. H. P.

The heat in the condenser per stroke of piston is 175,46 c., and the final temperature of the water of condensation $f=30°{,}50$; the weight of steam consumed is 0,3065 k. per stroke; the mean counter pressure under the piston during escape to the condenser is $P_c=0{,}368$ k. per square centimeter; giving a temperature of steam $T=73°{,}49$; and we have

$$\beta=628{,}91 \text{ c.}; \quad q=73{,}72 \text{ c.}; \quad r=555{,}19 \text{ c.}$$

The water carried by the steam is

$$m=\frac{0{,}3065\ (628{,}91-30{,}50)-175{,}46}{555{,}19}$$

$$=0{,}0143 \text{ k.} \quad \text{or} \quad 4{,}67 \text{ per cent.}$$

ENGINE WORKING WITH MOIST STEAM ; 136,46 IND. H. P.

The heat in condenser per stroke is 201,50c.; the final temperature $f=32°,65$; steam consumed = 0,3762 k.; counter pressure $P_c=0,367$ k.

$T=73°,42$: $\beta=628,89$ c.; $q=73,65$ c.; $r=555,24$ c.

$$m=\frac{0,3762\ (628,80-32,65)-201,50}{555,24}$$

$=0,04106$ k. or 10,91 per cent.

For first engine:

Steam = 0,27035 k.; water=0,03615 k.; or 11,80 per cent.

For second engine:

Steam=0,2813 k.; water=0,0949 k.; or 25,23 per cent.

In the first case we have 4 per cent. of water carried by the escape steam ; in the second, 10,91 per cent. It follows that $11,80-4,67=7,13$ per cent. in the first engine were evaporated upon the walls, and in the second $25,23-10,91=14,32$ per cent.; just twice as much ; as is also the case of engines with and without steam jackets.

It has been shown how in case of condensing engines the weight of water that passes directly to the condenser is determined, knowing that the steam is moist and the proportion of water it contains ; suppose that the escape is cut off at four-fifths of the course; it is then easy to determine the value of the internal heat of the mixture remaining in the cylinder and to follow the variations during the period of compression. It is necessary to experiment upon an engine with a single cylinder, so as to be able to regulate the compression, which can almost always be done with engines having four slides or valves, where the movement of distribution is independent of that of admission.

Further experiments wlll probably confirm the new theory of Zeuner; that the compression in the dead spaces in an ordinary engine, if pushed to the point of initial pressure, annuls the effect of dead space. The engine then acts as one without dead space, the escape going on during the entire stroke of the piston. We congratulate ourselves upon being the first to give experimental proof of this principle, so important in practice in view of the fact that Woolf's engine realizes an economy of 10 per cent.

RAIN WATER IMPURITIES—THE RIVERS POLLUTION COMMISSION.

From "The Engineer."

The second part of the last report of the Rivers Pollution Commissioners relates to the classification and chemical composition of the potable waters of Great Britain. Six different kinds of water are specified, the first being rain water. In illustration of this part of the subject there is an excellent hydrographical map of the British Isles, prepared for the Royal Commission under the superintendence of Mr. G. J. Symons. Different tints of color indicate the difference in the amount of the annual rainfall in the various parts of the United Kingdom. The greater the rainfall, the deeper the tint, and a glance of the eye at once detects where the heaviest fall takes place. Beginning with the highest figure on the scale, namely, above 75 in., the most southern point is at the summit of the Devonian range, in the region of Dartmoor Forest. Traveling northward the next instance of the kind is round about Plynlimmon. Both these rain areas are oval spots, the first about eleven miles and the second about fifteen in length, by six or seven miles in width. The Dartmoor ellipse is surrounded by an annulus, or zone, about four miles across, where the rainfall is less than 75 in. and not less than 50 in. A patch where the rainfall is from 50 in. to 75 in. occurs on the mountain range west of the Tamar, where the hills culminate in a point of great elevation. Reverting to the mountains of Wales, we observe a

patch of the maximum tint, not quite forty miles long, extending south-east from Snowdon. All down the Cambrian range, and southward over the high hills north of Merthyr Tydfil, there appears the tint which corresponds to the second gradation of rainfall, namely, from 50 in. to 75 in. From the centre of the Snowdon area, drawing a line across the country to Liverpool, it is singular how rapidly the rainfall decreases. For only three or four miles we have the second gradation, and we then enter on a strip scarcely nine miles wide, where the rainfall is from 40 in. to 50 in.; a still narrower tract has from 30 in. to 40 in. of rain. Over a yet narrower width the fall is from 25 in. to 30 in., and then to the south-west of the Dee there is a slip of about eight miles in breadth, where the fall is as low as anywhere on the map, namely, less than 25 in. From the verge of the greatest rainfall to the verge of the least is thus about twenty-five miles. Starting from a point a little northward of the centre of the Snowdon area, we travel over the scale even somewhat quicker. At Liverpool the rainfall increases again, being 35 in. per annum.

It might be thought strange that we have not yet mentioned the Irish rainfall; but the fact is, that no part of Ireland seems to have a rainfall exceeding 75 in. An area of about 35 miles square round about the Lakes of Killarney has from 50 in. to 75 in., and a small patch at Valencia has from 50 in. to 60 in. With these exceptions, the rainfall along the whole western and southern coast of Ireland has a range of between 40 in. to 50 in. South of Belfast, about Dundrum Bay, the scale sinks to 25 in. or 30 in. The remainder of the Sister Isle, taking the eastern side, excepting the south-east, and including all the centre, has a depth of rain between 30 in. and 40. On the Blackwater and the Lee this low scale comes to withih twelve miles of the Killarney area. The area of this moderate rainfall also stretches westward towards Galway Bay, until its distance from the sea is little more than ten miles.

Returning to Great Britain, we have to proceed to the Cambrian group, in order to find a rainfall exceeding 75 in. Here Helvellyn occupies the centre, and the longer axis of the ellipse runs from east to west for about 25 miles. Skiddaw and Sca Fell are pretty nearly on the extremities of the shorter axis. A zone of between 50 in. and 75 in. of rainfall surrounds this wetter portion, and also sends off a lobe to the south-east. Two areas of this second gradation, north of the Solway Firth, point us to the Scotch mountains where the Dee and the Nith find their head waters. Perhaps we ought to have mentioned, in regard to Wales, that the centre of the Isle of Anglesey has a patch—a very small one—of this kind. In this map Scotland is famous for a long, dark patch, showing a rainfall exceeding 75 in., all the way from the Firth of Clyde, across Ben Nevis, into the county of Ross. Altogether, this tract of country is 100 miles in length, with an average of fully 20 miles in breadth. An equal depth of rainfall shows itself in a small area to the westward, reaching from the Isle of Mull nearly across the mainland on the north. The Isle of Skye has another of these maximum patches, and furnishes the most westerly example of this heavy rainfall in the kingdom. The rainfall in the Isle of Lewis is between 40 in. and 50 in.

Along the extreme south of England, not going further north than Guildford, and taking a line from Ilfracombe to Ashford, there is a tract of country where the rainfall is from 30 in to 40 in. From Portsmouth, along the immediate vicinity of the coast to Dovel, and very nearly to Ramsgate, is an area where the fall is from 25 in. to 30 in. This area also sweeps round to the north of the one previously described, but keeps to the south of London. It touches the estuary of the Severn, whence it is driven somewhat southward by the heavier rainfall of the Mendips, and then goes off to the north round the base of the Cotswold Hills, travelling north-west to Liverpool Bay, and due north by a narrow strip through England to the Firth of Forth, reappearing at the Moray Firth. It also possesses a patch of considerable extent along the Yorkshire Wolds, and another one to the north-west of London, apparently due to the Chiltern Hills. Finally we come to the area of least rainfall—namely, less than 25 in. This may be described as

starting from the North Foreland, Dartford, and Reading, and sweeping away all up the eastern part of England to Sunderland, reaching laterally from the German Ocean to Buckingham, Nottingham Leeds, and Stockton-on-Tees. As it goes through Yorkshire it has a very wet region near at hand on the west. There are also the Chiltern patch in the south and the area of the Wolds in Yorkshire. The Royal Commissioners make no detailed allusion to the hydrographical map in their report, but certainly it is by no means the least interesting feature in the volume. A contour map of this kind would be especially valuable, as immediately showing the effect of elevation on rainfall.

Rain is no sooner discharged from the clouds than it begins to undergo pollution. The "freshness" of the air after a sharp shower indicates the nature of the process which has been going on. The falling drops have been literally "washing" the atmosphere, carrying down with them the floating particles of dust, and absorbing certain gaseous matters. Near the sea, in particular directions of the wind, the rain-drops become impregnated with a certain portion of salt. In the neighborhood of alkali works the rain will be sometimes acid. In order to obtain rain water in a fair degree of purity, the Commissioners caused a leaden rain collector, the thousandth part of an acre in extent, to be erected in the middle of an arable field on Mr. Lawes' experimental farm at Rothamsted, near St. Albans, twenty-five miles from London, and 420 ft. above sea-level. In several cases the rain water thus collected exhibited on analysis a degree of pollution which could only be occasioned by some accidental cause. The only samples really to be relied upon are those which were collected under personal supervision. These samples, fifteen in number out of the total seventy-one, were much less contaminated with organic matter as compared with most of the others. Still, it was found that even this specially collected rain water contained more organic polluting matter than that which appertained to sundry springs and deep wells. The superior purity of the latter waters is attributed to "exhaustive treatment by natural intermittent filtration." In the best samples of rain water the organic elements averaged 081 in 100,000 parts. Deep well waters in the new red sandstone had only 050 parts, in the oolites 047, and in the chalk 067. Spring waters from granite and gneiss rocks had 050 parts, from silurian rocks 065, from Devonian rocks and old red sandstone 066, and other examples might be cited.

The total solid impurity in the rain falling at Rothamsted, in the best samples, averaged 2.97 parts in 100,000 of water. The quantity varied materially with the direction of the wind, the south-west wind bringing the greatest quantity, and the north-west the least. The wind had less effect on the proportion of organic impurity than might have been expected. Nevertheless, when the wind blew from points between south-east and north-east, it delivered rain more highly charged with organic impurity than when coming from any other quarter. The average proportion of "mineral nitrogen" also varied with the wind, being highest when the wind was south-east, a direction which rendered it liable for the rain-clouds to pass over London before reaching Rothamsted. The south-west wind deposited rain which did not contain one-third as much nitrogen as that which came from the sout-east. Chlorides were most distinctly present when the wind blew from the north-east, coming from the centre of the German Ocean. The rain from the south-east had only one-thirteenth as much chlorine as that from the north-east. A sample of rain water collected by the Commissioners at a height of about 100 ft. above the sea at Land's End, when a strong wind was blowing from the south-west, contained no less than 21.8 parts of chlorine in 100,000. The hardness of rain-water ranges from zero to 10 degrees. But the higher degrees in this range are due to strong winds from the sea along the coast-line. At Rothamsted, in the whole seventy-one samples, the hardness never exceeded 1.7 deg., and averaged only 0.49 deg.

Dew and hoar frost are less pure than rain, a result which accrues from the circumstance that these forms of water are condensed out of the stratum of the atmosphere which is nearest to the earth's surface, where impurities are

more prevalent than in higher regions' The average of the organic elements per 100,000 in the samples of dew and hoar frost in the leaden collector at Rothamsted was 0.34, whereas the average in the entire seventy-one samples of rain was only 0.116. A large proportion of ammonia was also found in the dew and hoar frost, the average being as high as 0.198, whereas the average of ammonia from all the rain-water samples was only 0.050. The excess in the dew and hoar frost is attributed to the continuous evolution of ammonia from the manured land, and the presence of putrescent animal matter near the surface of the earth. The leaden collector, we should observe, was raised 2 ft. above the ground.

One sample of rain water was collected at Lancaster-gate, Hyde Park, on a day in November. The organic elements were 0.423, and the ammonia 0.210. The chlorine was 0.50, and the hardness—entirely permanent—was 1.1 deg.

It thus appears that rain water, fresh from the clouds, is not so uniformly free from impurities as is commonly supposed. The Commissioners tell us that rain is in reality "water which has washed a more or less dirty atmosphere." It is described as "laden with mineral and excrementitious dust, zymotic germs, and the products of animal and vegetable decay and putrefaction." A tumbler of rain water, taken as the liquid falls to the earth, contains as much impurity as a man would inhale from the atmosphere in eight days. Few people have been aware that heaven threw so much dirty water in their faces. It is not the sky, but the earth, that gives us pure water. The clouds gives us a modified kind of sewage, and the morning dew is anything but nice stuff to wash with, much less to drink. Some of the Rothamsted rain water contained arsenic, and in other instances there were traces of phosphoric acid. The fact is that the rain has to undergo the process of intermittent downward filtration through the earth's strata before it is fit to drink. The Royal Commissioners tell us that in Great Britain, and more especially in England, we shall "look in vain to the atmosphere for a supply of water pure enough for dietetic purposes." Impure at first, rain water becomes far more so after washing the slates, tiles, or thatch of a dwelling, and running into a tub or tank. "Briggs's soft-water cistern, Brook Hill, Greaseley, Notts, June, 1871," had 126 parts of solid impurity in 100,000; while the pervious sewage or animal contamination ran as high as 84.1790, with 11.50 of chlorine, and 55.7 degrees of hardness, of which 51.5 were permanent. Altogether, this delicious "soft" stuff was a good deal stronger than average London sewage. Of eight samples of rain water stored for domestic use, only one was fit for its destined purpose. Five of the eight were "very badly polluted," one of the worst being obtained, from a tank at Sheffield barracks. It is, however, a fact to be noted, that the rain water from a tank near Spalding, although unfiltered, gave no indication of previous animal contamination.

THE NEW BEIRUT WATER WORKS.

By JOHN C. HURD, Esq.

Written for VAN NOSTRAND'S MAGAZINE.

The prospect that some great political change will soon occur in the lands bordering the Eastern Mediterranean, makes it likely that particular interest may soon be freshly awakened in respect to many localities which are ordinarily remembered only in their connexion with ancient and mediæval history. The capacity of Palestine and Syria to become the peaceful scenes of modern commercial and industrial energy, as they have been for centuries the sacred battle fields for successive invaders, of various race, faith and civilization, may then become matter for practical valuations.

Already, for some years past, one city in Syria, Beirut, has been experiencing a renewed growth and a remarkable development in material progress. When, in 1831, under Mohammed Ali, Beirut,

was made the quarantine station for Syria, and, indeed, its capital city, the population was about five thousand, when Mr. Thomson, in 1860, wrote his well known work "The Land and the Book," he thought it had risen to about forty thousand; and it is now estimated to be nearly one hundred thousand, of whom probably not more than one-fourth are Moslems. Very little is known of the earlier history of the place, and the city is not named in any Biblical narrative. It has, however, been an important place at various distinct periods: probably, even under the Phenicians, and certainly under the Greek empire of Alexander's successors, and under the Romans. It was deemed the most beautiful and salubrious locality at the head of the Levant. It enjoyed the privileges of a Roman colony in the time of Augustus. When Herod Agrippa, otherwise known as Agrippa the Great, held Syria and Judæa with almost royal authority, under the Emperor Claudius in A. D. 41, he adorned the city with numerous public buildings in the grandly luxurious style characterizing the Imperial administration. This magnificence was almost obliterated by the earthquakes which, in the reign of Justinian, desolated many cities in the Eastern portions of the Empire. Some of the granite columns may still be seen beneath the waters of the harbor, and others incorporated into the modern mole or breakwater.

We may assume that Roman architects would nowhere omit provision for baths and fountains. There are still existing within the city several remarkable wells pierced into the rock; one, it is said, being one hundred and fifty feet in depth. The name of the city, indeed, is thought to have been derived from the word *beer*, signifying a well of water, in the Semitic languages. A canal was cut by Djerra Pacha to bring water from the small stream nearest the city called Nahr Beirut, River of Beirut. But the care of the ancient rulers for a copious supply of water is attested by the remains of a great canal aqueduct, now dilapidated as to the part nearest the town by its having within a recent period been demolished to afford ordinary building material. Mr. Thomson thought that, before this took place, this aqueduct might, at a moderate expense, have been made to serve its original purpose. Its length was twenty miles, and its starting point in the Lebanon was two thousand feet above sea level. Where it crosses the "River of Beirut," by a conduit twenty feet wide built of cut stone on three tiers of arches, still standing, the canal is one hundred and sixty feet above the bed of the stream. At this elevation it meets abrupt cliffs through which it passes by a tunnel cutting, to proceed on arches again, across the plain of Beirut. Remains of an aqueduct, probably still more ancient, cut through the rock under the existing city have also been discovered.

Considering the desolation which the country has continuously experienced during the last thirteen hundred years, it is a most interesting fact that Beirut to-day, is again supplied with water from the interior, and that this is done according to the modern system of hydraulics. To the American visitor who notices for the first time, in the pavement, the iron plates with the Roman capital letters, B.W.W., it seems strange that these initials should answer as well for "Beirut Water Works," as for those of Boston. The natural source for this modern supply is found in the *Nahr el Kelb*, or the *Dog River*, which with the ancients bore a name of similar signification, *The Lycus*, often mentioned in the local history. It is but a very short distance from the place where it empties itself into the Mediterranean to a narrow pass, between the rather inconsiderable stream of water and beetling cliffs which for thousands of years has been known as a highway of great commercial and military importance The limestone walls still display the sculptures and inscriptions here carved on them by successive nations in their day of strength and pride. Egyptian, Assyrian, Persian, Greek, Roman, Moslem and Crusader, have each in turn left here their memorial tablet. At various heights in the rocky flanks of the gorge are vast caverns, more or less accessible, ascending or descending in a labyrinth of chamber, some hung with huge stalactites, some traversed by streams descending in water falls to natural reservoirs ultimately communicating with the river. Others are accessible by boat from the stream at their entrances, and out of one of these issues

the principal feeder of the river; the ultimate source of all being Mount Sunnin, the tops of which are often seen from the city, covered with snow. Among the curiosities of the neighborhood is a natural bridge over the stream, which is now used as part of a traveled road, with a breadth of one hundred feet, the arch being at a height of two hundred feet and a span of one hundred and fifty. This undoubtedly is a relic of some more ancient tunneling wrought by primæval streamlets.

The water for the city is taken at a height of seventy-four feet above the sea by a conduit partly built up in masonry and in part tunneled through rock, which carries it to the pumping station, a distance of nearly three miles. Here the water is passed through filtering tanks, and then by turbine wheels worked under a fall of sixty feet of water, is subjected to a force sufficient to carry it to the city, a distance of about eight miles. The iron pipe, through which it is sent has a diameter, at the pumps, of twenty-four inches, which is reduced, gradually to eighteen when near the reservoirs over the town. These, two in number, are respectively at the levels of three hundred and twenty-five and two hundred and twenty-one feet above the sea. From these it is distributed immediately by pipes for ordinary uses. The supply is estimated to be quite enough for the domestic consumption of a population nearly double that of Beirut. But it is probable, in view of the tastes and habits of the inhabitants of the East, that a large proportion will be required for ornamental fountains. The water reached the town in the early part of March last, and in June there were already hundreds of houses supplied with it. The Porte had made it a condition in the franchise that one-third of the capital should be offered to the people of Beirut, but there was but one native of the town who subscribed—a gentleman who is now the local director, a man participating in the more enterprising spirit of western countries. The people in general, probably, saw little difference between such an investment and one in their national loans; in which they never, at least not voluntarily, take a creditor's position. English capital for the most part has supplied the means. The work has been conducted throughout to its completion by a British engineer, Mr. W. J. Maxwell, of Belfast. Natives, under European gang masters, were employed; except for the tunneling and machinery. The main tunnel is nearly eleven hundred yards in length, in which distance four shafts, the deepest being two hundred and thirty feet from the top of the rock, were sunk for the construction, allowing the horizontal piercing to proceed from ten faces at once. On this part of the construction, Italian as well as native laborers were employed, working night and day, and it was opened through in fourteen months. Mr. Maxwell, on the completion of the work, has returned to England. M. Briffeux, a very courteous French gentleman, is the superintendent at Dog River.

Beirut is even now an exceptional city in the East. It has various flourishing industries of silk, wool, cotton, iron and jewelry; with constant and increasing direct communication with Europe and America. The old narrow streets have in some quarters been widened. There are European hotels, pleasantly situated and well kept. There may be found a highly cultivated society from among the families of the merchants of various European countries, the clergy of various creeds, and the ladies and gentlemen connected with the missions for evangelization and schooling, whose headquarters for Syria are in the city. Reliable physicians, educated in Europe or at the medical college in Beirut itself, are at hand. For invalids seeking more complete change of scene, with a mild and healthful residence among agreeable surroundings, the place presents many attractions. Damascus is reached by diligence over a Macadamized road, recently made by a French Company, and for those able to travel on horseback with a tent equipage, there are excursions to the Cedars of Lebanon, Baalbec, and on to the Holy Land, for which Beirut is a good starting point.

If the Euphrates Valley Railroad should be constructed, Beirut will probably become its terminus on the sea. When the British Government, in 1840, saw fit to maintain the sovereignty of the Porte over Syria, against the Egyptian dominion, the city was bombarded from

an English fleet. It seemed probable that the contrary policy will now be pursued, and that Egypt will be the ally in any of the struggles that may ensue. Whose *protection* it shall be that will be extended over Syria and Palestine may be more questionable.

The traveler in those countries even now feels that it is England, or more properly, the British empire of commerce that is "in the air;" far more than any other European influence. Perhaps the battle-cry "God for" Victoria, "England and St. George" may be soon shouted in the very plain close by Beirut and around the chapel, now a Moslem shrine, dedicated to his memory, where the warrior Christian had his celebrated tussle with the dragon monster.

AIR BAGS FOR RAISING VESSELS.

From "Engineering."

Air being seven hundred times lighter than water, a bag made of a very light water-tight material, when filled with air affords easy and powerful means wherewith to raise sunken bodies. Air bags are convenient for stowage and transport, because when not in use they occupy very little space, while at the same time when wanted they can be expanded into large dimensions. The greater the weight of the body to be lifted by means of air bags, the larger of course must be their displacement, and as the bags are generally manufactured of certain fixed dimensions, the weight of the submerged body must determine the number of air bags to be applied.

The first to suggest the use of air bags for this purpose was Professor St. Claire, of the University of Edinburgh, who proposed them in the year 1785. But as the india-rubber industry was then but barely developed, air bags could not then have been manufactured of that material so as to be of practical use. So recently as in 1864, air bags were for the first time practically applied by Bauer for raising the steamer Louis, which sank in the Lake of Boden. But on that occasion, owing to the bags being pear-shaped, they could not sustain the pressure and gave way. The idea of using the air bags in Russia originated with M. J. Alexandrovsky, and the system was adopted in 1865 at the time when the turret ironclad Smertch foundered in the Baltic Sea. Mr. Alexandrovsky was supported by Admiral Popoff, of the Russian Imperial Navy, who assisted him greatly in bringing his invention into practice, carrying out experiments so as to render the air bag system what it now is, namely, a very valuable means of raising ships, &c., and which has already rendered good service to the Government and commerce of Russia on several occasions.

The air bags adopted in the Russian navy when inflated are of cylindrical form, measuring 12 ft. in diameter, and 20 ft. in length. The useful part of their displacement or their lifting power in practice averages 60 tons. Air bags measuring 15 ft. in diameter and 20 ft. long will lift about 100 tons, and cost, according to the number required, from £375 to £350 each in St. Petersburg. The skin of the bags, of the sizes mentioned, is composed of three layers of the thickest canvas, saturated with india-rubber. Between each of the canvas layers is a sheet of india-rubber. The two inner layers of canvas are made up of strips sewn together along their edges, and laid in the direction of the length of the bag, whilst the third or external layer is made of canvas strips surrounding the bag circumferentially. The strips of this last layer thus cross those of the layers underneath it. This arrangement of the skin layers secures in the bags the required amount of resistance and durability. The external surface of the bag is fitted with special straps through which it is surrounded with a close, strong rope net, which increases the strength of the skin, and a layer of matting is interposed between the skin and the rope net.

In order to distribute over the whole surface of the bag the strain to which it is subjected when lifting heavy bodies, the bag is enveloped in a series of longitudinal and transverse, or circular hempen cables. To the lower ones iron eyes are fastened, which afford means to connect the chains securing the bag to the object to be raised. When necessary an oak beam 12 ft. long and 14 in. or 16 in. square is attached to the cables which surround the bag transversely ; and to this beam the connecting chains are made fast. Each of the air bags is fitted with a valve, which is screwed in at the top and in the centre, together with an india-rubber hose, by means of which air is forced into the bag. At the ends of the bag, also in its upper part, are two smaller valves with tubes intended for letting the air out, and for holding the pressure gauge, which is applied for the purpose of ascertaining the amount of pressure inside.

In the interior of the bag, along its bottom, two short lengths of hose are sewn in so that they cannot move laterally. One end of each of these pipes which is open terminates close to the end of the bag and in the interior of it, whilst the other end passes out at the opposite end of the bag at the bottom, and is fitted with a safety valve, which opens when the bag is fully inflated with air and the pressure begins to exceed the surrounding water pressure. By means of these two safety pipes and valve the bag is secured from bursting, and the pressure of the air within it distributes itself evenly in both ends of the bag. The bottom part is fitted with a man-hole sufficiently large to admit the entrance of a man for inspecting the interior of the bag and for repairs.

In order to lift the sunken vessel, it is necessary first to send down divers to examine her condition, and to find the spot where it would be most convenient to pass chains or cables underneath her keel. For this last purpose the divers at first pass a thin rope underneath the bottom of the vessel, which is followed by a rope of greater thickness, attached to the first and terminating at the other end by a chain or the cable. It sometimes happens that the power of the divers below, and that of the windlasses above, though sufficient to draw a thin rope under the vessel are insufficient to haul a thick cable. In such cases an air bag is attached to the end of the thin rope, and this bag being inflated acquires an ascending power sufficient to carry with it a cable of any required thickness. This method was successfully adopted, when a vessel sunk in a depth of 15 fathoms was being raised, and when the power of 200 men with windlasses proved to be insufficient to draw the chain underneath the vessel.

When several chains have been drawn underneath the bottom of the ship the air bags are attached to the ends of each of them, as near to the bottom of the ship as possible. The bags being inflated by means of air pumps cause the ship to rise. Before pumping air into the bags, care is taken to connect together all the chains which surround the hull of the vessel in a transverse direction, so as to form a longitudinal continuous belt, which uniting all the chains into one system, prevent the end pairs of air bags sliding off from beneath the extremities of the vessel. As the ship rises the surrounding water pressure decreases and the excess of air passes out from the bags through the safety valves, with which each air bag is provided.

This method of raising vessels and other sunken bodies by means of air bags is of very great importance, especially when the work has to be performed in the open sea, because in rough weather the bags without any air in them can be left under water with buoys to mark their position, until the weather becomes more favorable and the sea calm.

When lifting vessels from great depths, the work must not be accomplished by one process, that is, the whole number of air bags required to complete the work should not be applied to the ship at one time. This precaution is necessary, because, when the vessel, tied up with chains and provided with the full number of air bags, ascends rapidly from a great depth and gets to the surface of the water, it is raised, by means of its acquired momentum, higher than is consistent with equilibrium at the surface. Eventually after attaining an unbalanced position, the whole is submerged again. This arises from the circumstance that from the moment the

ship leaves the bottom of the sea and during her ascent the surrounding water pressure is gradually decreasing and the air from the bags is passing out. Therefore, at the time when the ship reached the surface of the water, the bags would not possess the amount of lifting power necessary to keep her on the surface. Accordingly the ship would return to the bottom. To prevent this one, two, three, and in some cases four bags (according to the size of the vessel), out of the whole number required are fastened to the chains, which surround the vessel, not close to her, but at a depth of some two or three fathoms below the surface of the water. By such distribution of lifting power, the vessel, having separated herself from the bottom of the sea, would ascend until the upper bags reached the surface of the water. The whole system is then towed to another place, where the water is shallower than where the wreck occurred. The air bags which reached the surface of the water at the first operation are again submerged and are tied to the chains several fathoms lower down. By repeating these operations several times, according to circumstances, the ship will be brought to the surface gradually and by easy stages with the certainty of success.

These precautions are also necessary in those cases when, as it sometimes happens, the sunken ship, after having separated herself from the bottom of the sea, would be raised not horizontally, but with one end higher than the other. By having several air bags, out of the whole number, attached at a depth of a few fathoms below the surface, it insures that the rise of the higher end of the vessel will be limited only to the height equal to those few fathoms, and the chains with the air bags surrounding the ship cannot slide from underneath her. This method of working affords a sure means of ascertaining whether there is any necessity to increase or decrease the lifting power at either extremity of the vessel.

In the year 1869 a merchant schooner foundered in the Baltic, and in order to save her heavy cargo, consisting of pig iron, air bags were made use of. This case proved how powerful the air bags were, because, when the upper part of the vessel was surrounded by the longitudinal belt of chains with the air bags attached to it, her deck, with the whole of the masts, spars, and fittings, together with the upper strakes of her sides, were torn away by the power exerted by the bags, and were carried up to the surface, the breakage occurring just along the line where the bags were applied. After having thus opened the hold her cargo, and afterwards the vessel herself, were lifted up easily and successfully. The next useful work performed with the air bags was the lifting in 1870 of the gunboat Metch, which sank in the roads of Tranzund in a depth of 21 ft.

Soon after this in the same year the steamer Ilmen, which had foundered near Viborg, was raised. The work was completed in the short space of ten days, thus proving the simplicity and ease with which the air bag system can be applied.

In the same year the ironclad Sevastopol was lifted for repairs by means of bags, so that access was obtained to the wooden planking separating the armor from the copper sheathing. The edges were calked and the planks replaced by new ones. By these means in five days only, and with very little expense, the leakage from which the frigate suffered in 1869-70, and also the destruction of the lower armor plates due to the action of copper sheathing, were successfully stopped. Had not the bags been employed, it would have been necessary to place the frigate in dock, and as the docks at Kronstadt, at that time, were not so deep as they are now, this work would have necessitated the removal of her armor—a heavy and very costly job or the frigate could not have been commissioned until the new dock was completed. During the same year also, air bags were used for raising the stern of the ironclad frigate Minin. With the help of two barges and four air bags, the frigate was successfully conveyed over the Neva bar to Kronstadt. In 1870 the imperial yacht Standart being raised by means of eight air bags was conveyed in a similar manner over the Neva bar. In this work also the use of air bags greatly reduced the expense and saved much time. In the same year the air bags were utilized for lifting up the stern of the ironclad Prince Pojarsky,

when she was brought through the gate of Petrovsky Kronstadt Dock, where the ship had her armor plates put on and whence she could not be taken out without taking these plates off again.

In 1872 in Biorke-Zund, a vessel sank in 90 ft. of water. It was intended to lift her by means of barges, but this attempt failed, after much time and money had been spent. On the attempt being made with air bags, the work was successfully accomplished, notwithstanding that this vessel, owing to her cylindrical form, her comparatively small size, and her very heavy weight, proved to be very difficult to raise. The lifting of this vessel thus from the bottom of the sea showed that the work could only have been successfully carried out by means of air bags.

The system afforded no less important aid in 1873 in the Black Sea, where the necessity occurred for changing the pitch of the propelling screws of the Popoffka Novgorod. The form of this ship did not allow her to be taken upon any slipways existing at that time. This work required but three bags, and by means of them the stern was lifted to a height of 5 ft.

Last year a merchant steamer, the Dornkat, which foundered in 11 fathoms of water near London Lights, in the Baltic, was lifted by means of 8 air bags. Notwithstanding that at the beginning of the work the steamer was surrounded on all sides by the ground at the bottom of the sea and was buried in it, and that the work was carried out in an open sea, the steamer was successfully raised.

In the autumn of last year, by means of the air bags, the stern of the Popoffka Novgorod was lifted twice for the purpose of lengthening the blades of the propelling screws and to change their pitch. This year air bags have been usefully applied on several occasions, and at present they render great services in the construction of the new bridge across the Neva in St. Petersburg. In this case they are used to keep in a vertical position the iron caissons during their erection. It will thus be seen that the air bag system is in every respect one which may be of great value to the royal and mercantile navy.

THE LATEST NEWS ABOUT RAILWAYS.

From "The Builder."

So much attention has recently been directed, in various quarters, and with various objects, to the actual condition of railways, that our readers may be glad to have a few words on that important subject. Absolute novelty, indeed, can hardly be expected to characterize our remarks. But even novelty is not absent; while information as to what is more important, steady progress, either occurs or is demanded at every turn.

So accustomed have we become to the greatest mechanical triumph of the nineteenth century, that we almost cease to note how absolute is now our dependence on this method of internal transit. In the good old times, when one, two or even as many as four-and-twenty four-horse coaches ran, in the course of the four-and-twenty hours, past some famous roadside inn, an allowance of a horse per mile was considered adequate to the requirements of the very first style of travelling. When the coaches were full each horse would have to draw four persons; and if the same team ran twice in a day over an eight mile stage each horse would draw four persons for sixteen miles, or one person for sixty-four miles. We are not in possession of the actual number of horses thus engaged, but we may call to mind one fact which no longer exists, and that is the great disproportion in the amount of travelling for business purposes which was wont to distinguish the winter from the summer season, arising from difficulties during the latter that now no longer arise.

At the end of 1873, there were existing, on the 16,082 miles of railway open

in the United Kingdom, 11,435 locomotive engines, which were used for the traction of 362,785 vehicles of different descriptions. Thus, the locomotives amount to 71 per mile, and the gross total of vehicles to 22.56 per mile. But carriages used for the conveyance of passengers only are only 24,634, or a little more than 1½ per mile of railway. There is no distinction given between the passenger and the goods engines; but as the vehicles not used for conveying passengers which are attached to passenger trains amount to 9,128, we have a general plant for the passenger and light parcel circulation of 33,762 vehicles; against cattle, merchandise, and other general wagons, amounting to 329,023, making the dead traffic provision very nearly tenfold that for the live human transport. We may thus conclude that something like 1,200 will be the proportion of exclusively passenger locomotives.

Whatever may be the exact distribution of the engines, this running stock of 33,762 vehicles provides for a circulation amounting to 455,320,188 passenger journeys; besides the uncounted journeys of 314,579 season-ticket holders. The gross weight of minerals and general merchandise conveyed is returned at 190,953,457 tons. If we allow four journeys a week for every season-ticket holder, and two hundredweight for each passenger and his personal luggage, we shall find the passenger tonnage amounts to rather less than 50,000,000 tons, or about one-fourth of the merchandise weight. The total receipts from passenger trains amounted, in 1873, to the sum of £23,853,892; that from goods and minerals to £31,821,529. Thus the passenger income is 43 per cent., the goods income 57 per cent., of the total. The expense of wear and tear and interest on capital sunk in construction of the vehicles destined for the two services is difficult to ascertain. But against the higher cost of the passenger vehicles may be set the greater speed at which they run, and the very much shorter period of time for which they are idle. Taking these elements into account, it is probable that there is not a very material difference between the earning power of equal sums invested in passenger and in goods vehicles. At this rough approximation something like 20 per cent. of the annual expenditure will be incurred in carrying on the passenger traffic, which earns 43 per cent. of the gross receipts; while the remaining 80 per cent. of expenditure, incurred by the goods traffic, only earns 57 per cent. of the gross receipts.

We do not, of course, state these proportions as absolutely precise. We give the figures on which they were based, which are those of Captain Tyler's report for the year 1873. They appear to us to be approximately correct. Our readers have the opportunity of checking them. They point to very important results. The gross total railway income of 1873 was £55,675,421, of which £30,060,112 were expended in working and maintenance, and £25,615,309 remained as profit, allowing an average dividend of 4.64 per cent, on the total capital of £588,320,308.

In other words, the average earnings of every train came to 67.71d. per mile; the cost per train mile being 36.57d.; and the net earning 31.14d. per mile. The total train mileage is 197,354,749 miles. Thus 54 per cent. of the gross returns are expended in earning them. Whether from the natural difficulty of the case, or from any other motive, those statements which might enable us to ascertain the relative net earnings of the goods and passenger traffic are absent from Captain Tyler's report. It is for this reason that we have entered into the analysis of one element of that distribution of cost,—the carrying power allotted to the two great descriptions of traffic. With a special machinery of nine-tenths of the whole provision for traffic, the carriage of three-fourths of the gross weight transported over the lines has earned only 57 per cent. of the gross revenue. According to this rough approximation, the portion of the income arising from goods, viz., £31,821,529, is earned at a cost of 75 per cent. of the gross charge, or of £22,545,084; while the passenger receipts of £23,853,892 have been earned at the cost of only 25 per cent. of the gross charge, or £7,515,028. That is to say, that the net earnings of the goods traffic have been only £8,967,637, or about 28 per cent. of the goods expenditure, while the net earnings of the passenger traffic have

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amounted to £16,338,864, or about 217 per cent.,—more than double the expenditure,—for the passenger traffic.

Rough as this approximation is, it is by no means certain that the disproportion would be reduced by greater exactitude. As it stands, it is clear that, even if it cannot be said that the goods traffic of our railways is carried on at a positive loss, it is carried on at a great relative loss, as compared with the passenger traffic. It results that a line constructed for the exclusive conveyance of passengers, supposing it to have full employment (which would be the case with many of our most important lines if they were thus restricted), would earn four times as much for the shareholders as a goods line, in proportion to the running expenses. When we come to divide the net profits over the capital, it seems to be pretty clear that a goods line alone would involve an annual loss, as its net train earnings would not pay 1½ per cent. on the capital. A passenger line alone would pay upwards of 15 per cent. on the capital. Therefore our actual dividends are kept down to below 5 per cent. by the goods traffic.

This consideration is one that eminently deserves the attention of railway proprietors. Any miscalculation we shall rejoice to have pointed out. It is pretty certain that the managers of many of the lines can, if they think fit, tell the actual differences in the profit of their passenger and of ther goods traffic. The practical part of the case lies here. Most of our lines are so choked with traffic that the construction of some mode of relief is only a question of time. Throughout the country exists a very elaborate system of water-carriage, which it has been the policy of the railway companies to discourage to the utmost, although in many cases the canal property is in their own hands. Are we, then, in order to leave the rails free for passenger traffic, to construct new lines for the heavy traffic alone, which will pay only 1½ per cent. on the new capital, or are we to endeavor to relieve the present glut by recourse to the cheap, though slow, method of water-carriage?

Full statistical returns generally enable an analytical observer to extract information which may not, on the face of these returns, be at first apparent. It is, however, remarkable that the report of Capt. Tyler is blank as to every particular that would enable us definitively to compare the relative profit of the goods and passenger traffic. The subject is one which must have so often engaged the attention of all competent railway managers, that the absence of such information is remarkable. It can hardly be accidental. We may be in error, but it certainly seems to us as if the returns had been purposely so constructed as to withdraw from the control of the shareholders any useful information on this subject. In our early returns as to the railway expenditure the outlay on land, works, and rolling-stock was always separately stated, as were also the legal and Parliamentary expenses. In the present return, all this has disappeared. We have elaborate statements of capital, how varied, and what are the dividends that it bears; but the very important matter of the objects to which the capital has been devoted is passed over in silence. We are thus unable to ascertain, even approximately, the cost of the different portions of this working-stock, of which the numeric items are given. This is a serious defect, and detracts much from the value of a report which ought to be exhaustive. The bearing of this silence on the point under discussion will soon become apparent.

If we consider that the locomotive stock enumerated has cost £1,500 per engine, which is probably a good deal under the mark, and that the carriage, wagon, and other rolling stock has averaged £150 per vehicle, we shall find that some seventy millions, out of a gross capital of 588 millions, have been laid out in working stock. We are under the impression that the figure is below the mark, but let it be taken as a guess. The plant required for the passenger traffic is, as we have seen, numerically only about a tenth of that required for the goods traffic. But as the more expensive carriages are to be found in this division of the working stock, let us assume that each passenger vehicle costs three times as much as each goods vehicle, and that the passenger plant thus stands to the goods plant, as to cost, as two to five. This would leave fifty millions as the cost of

the goods plant; and we shall be very glad to have the actual amount substituted for this rough guess. We cannot estimate the annual interest and deterioration of this plant at less than ten per cent. If we consider, then, that the railways were all made at a certain cost, irrespective of the traffic which they were intended to convey, we should have an annual sum of five millions to charge against the goods traffic, after running charges had been defrayed, before absolutely net earnings would accrue. But we have already seen that the earnings of this traffic, deducting working charges from receipts, on the principle of proportioning cost to weight carried, amount to only some nine millions sterling. This sum is now reduced, we see, to four millions sterling. As to the enormous outlay on the construction of stations, cranes, warehouses, &c., for goods alone, and the annual charges, carried to the general account, which are due to goods traffic, we have no means of forming an estimate. There can be little doubt that they would swallow the greater part of the remaining four millions. At any rate, it is extremely unsatisfactory that, whether we analyze the annual expenditure, or the distribution of capital, we find in each case that the information which would enable us to speak with certitude as to the relative advantages obtained by the railway companies from passengers and from goods traffic is, in each part of the returns, carefully kept out of sight. It is not an unnatural supposition that this has been done in order to prevent comparisons that must seriously affect the question of the true policy of our railway management. Sooner or later the economical law of working will become known. It will be better for the shareholders if it is sooner rather than later.

The policy of railway management, while it is a subject of national importance, may be said primarily to concern the directors and shareholders of railways. It is otherwise with the safety of railways. As to this every one of us is directly concerned. There have been more than usually numerous indications, of late, that the public attention is somewhat anxiously fixed on this subject. It was the only one on which the President of the British Association thought it necessary to bring forward new matter, thrown into tabular form, in his opening speech. It was discussed, with admirable temper and scientific precision, by Mr. Bramwell, in the mechanical section. It is the subject which has called forth an extraordinary proposal from Sir David Salomons, which he has brought before the world in a pamphlet, having first secured such profits as may flow from a patent. And the Board of Trade returns for the quarter ending June 30, 1875, which are just published, show that the loss of life daily incurred on our 16,000 miles of railways forms an appreciable item in the death-rate.

Sir John Hawkshaw has shown, by the sure method of statistical comparison, that the risk of injury faced by a railway traveller is, as matter of mathematical expectation, very trifling. Only one passenger has been killed, from causes beyond his own control, out of 13,165,000 passenger journeys, between 1846 and 1873. Only one passenger, under the same limitation, has been injured out of 4,045,000 journeys. And in the decade ending 1873 the deaths inflicted on passengers, in proportion to miles travelled, were reduced to two-thirds of the ratio that obtained in the preceding decade.

The daily press retorts on this statement with what some people call a common-sense view. "Don't tell us," says the public commentator *de omnibus rebus*, "about relative safety and proportionate accidents. Give us facts. You kill so many persons. Why is that? Somebody ought to be hanged, and the ouly question is who."

No persons are so loud and obstreperous in their demand for facts as those who are utterly unable to make any rational use of them. The real meaning of the demand generally is "I will not listen to argument. I don't care for your explanation; an accident is an accident, and you cannot talk it away." In actual truth, however, facts are generally of little or no use to the general auditor or reader, until they are collected, sorted, and collated by some one who has a due knowledge of their significance; and that is exactly what Sir John Hawkshaw has done in the present case.

There is, however, one point of view which we may consider as novel, if it were only from the fact that neither Captain Tyler, in his report for 1873; Sir John Hawkshaw, or Mr. Bramwell, in their papers at Bristol; Sir David Salomons, in his pamphlet on signalling; nor any other authority recently before the public, has supplied the information requisite for the statistical analysis which would enable us to investigate it as fully as we could wish. The railway service of this country is, in point of fact, a service of extreme danger, from mechanical causes. It is carried on at a considerable cost to human life. It is true that familiarity with danger, leading often to carelessness, may be detected, in most cases, to be the proximate cause of disaster. But however this human weakness may come into play (as it does, happily, in all circumstances of danger, or life would be far more full of apprehension than it is), it is the rapid motion of great masses of matter in the immediate vicinity of crowds of human beings that is the prime cause of danger. And this is a cause inseparable from the rapidity and ease of our travelling.

The actual number of the persons employed by the different railway companies is not given in either of the papers to which we have referred. Sir John Hawkshaw says, in round numbers, that it amounts to a quarter of a million. The total number of casualties on railways for the quarter ending June 30, 1875, was 1,431, of which 261 were deaths. Of the casualties, 933, 157 of which were deaths, occurred to servants of the companies. This gives a death-rate of 2.5 *per mile*, and an injury rate of nearly 15 *per mile per annum*. If we compare this with the colliery death-rate and injury rate for the year 1869 (when we brought that subject before our readers), we shall find a considerable difference in favor of railway safety. 1,116 lives were lost in that year by 854 separate colliery accidents; the total number of male persons employed in collieries being 345,446, of whom 282,473 were miners. It will be observed that deaths alone are given in the one case, deaths and injuries in the other. One live was lost out of every 309 persons employed in the coal mines, being at the rate of 3.23 *per mile*; or one-third more, proportionately, than in the railway service. In the latter it seems that there are about six injuries to one fatal injury.

We may look at this comparison in another light. The 1,116 lives lost in coal mining in 1869 were destroyed in the course of operations that resulted in the winning of 108,003,482 tons of coal; being at the rate of one life lost for every 96,777 tons of coal won. We have seen that the tonnage moved by our railways in 1873 may be roughly taken at a paying load, in goods and passengers of 240,000,000 tons. If we take the death rate of the last quarter as characteristic of the year we shall find the proportion to be only at the rate of one life for every 400,000 tons of load moved. The safety here is more than four-fold, in proportion to the work done. The danger arising from velocity is, to this extent, better watched against than the dangers arising from the peculiar circumstances in which the miner works.

A further measure of the natural danger attendant on rapid steam travelling may be taken from the fact that during the last quarter twenty-one passengers were killed, and 132 were injured "from their own misconduct or want of caution." This part of the return, which has no analogy to any other with which we can compare it, as a special value. We see that the system is in itself so dangerous as to cause 153 accidents in three months from the inadvertence of the sufferers. In the working of this system, moreover, a certain sacrifice of the staff occurs, which, although of a magnitude not to be slighted, is far less than that which occurs in the provision of one supply of fuel. And yet we find that only two passengers have been killed, and 182 injured in the same quarter, from causes beyond their own control. The number of passengers during the quarter is not stated; but from the data given for 1873, we estimate that it must have been considerably over 120,000,000. That only 184 injuries, two only of which were fatal, should occur in a circulation of 120,000,000 passengers, certainly denotes a very high degree of safety. A man cannot ride, drive, boat, or even walk the streets

of a crowded city, with so little risk of accidents, as he incurs when travelling in a railway carriage. To some extent his comfort and safety are insured by the risk of the servants of the company ; but even as to this, his supply of coal has paid a heavier life-tax than his provision for travel has involved.

Small as this personal risk is, it may be stated, with little hesitation, that it is not the fault of the civil engineer that it is not altogether extinguished. Mr. Bramwell has shown how analyses of the causes of casualties have led, in almost every instance, to the provisions of safe-guards that would be perfectly adequate if faithfully applied. The cause of railway casualty, in the present state of science, is almost exclusively economical. It is the neglect or disuse of precaution, whether in order to avoid expense or to avoid fatigue, that is almost invariably the cause of disaster. Over-working of railway servants,—which means undue provision for the requirements of traffic,—lies at the bottom of most of the trouble ; the natural imperfection of the human machine, when not over-worked, accounts for a comparatively trifling remainder. From this cause, we fear, there will always arise a certain element of danger, though an element that may be reduced to a very low value.

It seems tolerably certain that the engineering science of the day has arrived at the best distribution of precautionary measures under these three heads, viz.,—mechanical appliances, telegraphic communication, and human watchfulnes. All three are needed. It is almost invariably the last element in which failure occurs. It is, therefore, by an attention to the moral and physical condition of the railway servant that the sources of danger are to be, as far as possible, eliminated. For this reason ingenious inventors, who, like Sir David Salomons, are endeavoring to throw the duty of human watchfulness on mechanical automatic contrivances, are working in the wrong direction. It is not necessary to analyze Sir David's proposal of a complicated addition to the block system. Its adoption would add nothing to the advantage of that excellent system, but would substitute a mechanical method of indication very likely to get out of order, and therefore most treacherous in its action, for a plan which only requires inflexible enforcement to insure safety. And it would make this change for the worse at such an outlay,—upwards of a million and three-quarters,—as prevents the need of further discussion. It is a remarkable instance of the love borne by inventors to the off-spring of their own brain that reflections such as these should not have occurred in time to save Sir David the expense of printing his little book.

TOOLS.*

From "Iron."

The word tool may be said, when taken in its broadest sense, to include every mechanical device that man has conceived and embodied in a material form in order to aid his own efforts in the accomplishment of his own purposes, more especially where the application of force is implied. They range from the first smooth stone used by the savage up to the self-acting mule or the Walter printing machine, including even the locomotive engine, or any other higher development; for through them all, from the smooth stone upwards, one idea passes into another so gradually and imperceptibly that it is now impossible to draw a distinct line at any definite point, the conventional classification or nomenclature which is now employed being merely a matter of convenience to enable us to distinguish one sort of tool or device from another. The great point to realise clearly at the outset is this, that all mechanism, of whatever nature or by whatever name it may be known amongst

*Abstract of an address by Dr. Anderson, delivered at the opening of the Exhibition of Appliances for the Economy of Labor at Manchester.

men, is in each individual case the result of the material embodiment of an idea, that the original idea was first conceived in the human mind, and then by the means available at the particular period of the world's history man has been enabled to reduce the mental idea into a material, tangible form. According to Carlyle, the first tool used by the prehistoric man was a smooth stone, selected for a practical purpose, to be employed against his foe, or to aid him in killing wild animals for his daily sustenance. In course of time the idea would gradually dawn upon the mind of some other man of an ingenious turn, that if a long leather thong was attached to a stone, with the other end of the thong having a loop to pass over the right wrist, he could thereby save the trouble of having to look for and find the stone after each effort, and he could sit quietly under the shade of a tree in waiting for the prey, and hurl the stone without having to change position for its recovery; the assumed thong would thus be the first decided contrivance for the saving of labor.

Of the earliest invention of tools, or the first applications of mechanical force to perform work, there is no existing record. Man's first effort with tools lies far beyond the reach of history or even tradition. The tool arts existed for thousands of years before Greece had reached the period of her artistic greatness; the tool art was ancient and mythical long before Romulus or Remus had been fondled; even far beyond the time when the Egyptian pyramids were erected for then tools were in a highly advanced stage, of which there is ample evidence. Those great works were not carried out by the apprentice hand of man. In searching for the origin of tools we have to go a long way still farther back—away up into the somewhat mythical region of our own old fatherland, the home of the Aryan race, somewhere in Asia, where there is evidence that tools were familiar long before the Aryan swarms of colonists set out to people Hindostan, Persia, Greece and Rome, and nearly the whole of Europe. It is interesting to read the account of the ethnological investigations that have thrown light upon the condition of tools during that period. We read that the words relating to tools, industry and peaceful pursuits, to the domestic animals, to the weaving of cloth and the working of metals, have the same roots in the languages of all those nations, but that the words relating to war and most other subjects were originated by the several branches after the Aryan family had been broken up, thus showing that tools, the arts of peace and industry, must have been long established, otherwise the names of tools could not have been so firmly rooted in the minds of the entire race, to be retained in the memories of the whole stock in their respective colonies, when they, one by one, found a resting-place in other lands, including even our own little island home. On reaching the times of Euclid and Archimedes we find tools highly advanced; the principles of tools are clearly understood, and about 130 years before the Christian era there is a pumping steam-engine at work in the courtyard of Hero of Alexandria, the pump having an air-vessel attached to produce a constant jet of water, similar to the modern fire-engine of John Vanderheyden. Both Pliny and Cicero refer to the tool called a lathe, but it is doubtful if they mean the lathe tool of our time; it is more than probable that they refer to the class of lathe which is now extensively employed in Birmingham for spinning sheets of metal into bowls or dish-covers, but in those early days the sheet of metal seems to have been laid on the table of a sort of potter's wheel, which would afford the same result.

In the automatic or self-acting tools of this generation the great distinguishing feature of the larger number is this, that when once the tools are in working order they do not depend upon the attendant for the result. This condition is obvious in the tools of the textile manufactures, and almost equally so in the class of tools that are employed for the treatment of metal, wood and stone. In the latter, when considered in a general way, there is a family likeness running through them all, not so much in their outward appearance as in their principles of action, and still more in their adaptation to trace out the required form or pattern from a permanent copy embodied in the tool by a process of transfer. In the intelligent examination of such mechanism the first thing to ob-

serve is the manner in which this leading feature has been developed, and it will be interesting to compare in each separate tool how the primary idea of copying the form has been embodied in the material structure, because this is the very point where a man shows his superiority for ingenuity, skill, craft, or taste. Although the ways in which the idea of copying is embodied are innumerable, still it will be found that in almost each case the means employed are exceedingly simple.

To select, for example, the familiar tool called a lathe; it is chiefly intended to impart to materials true circles, straight lines, and flat surfaces, and all of those conditions must first exist in the tool. The bearing surface of the spindle neck must in itself be absolutely round in the strictest sense, otherwise the article operated upon will not derive a true circle from the revolution of the spindle. The mathematically true circle here referred to is practically very difficult to attain. There are many tools in the world that are supposed to be round, but which are not so in reality. An examination of the Whitworth gauges will best convey the idea of what is meant by mechanical truth and a true circle, each part fitting accurately into the other, yet perfectly free in every position. Then again the lathe has to afford absolutely straight lines of movement for the guidance of the cutting instruments, whereby the true circle derived from the spindle and dead-centre point is developed into a true cylinder, but not so unless the parent circle and straight lines are correct in themselves. If a perfectly flat surface is required from the lathe the cutting instrument must pass in a straight line transversely to the axis of the revolving spindle, and if the two are set absolutely at right angles to each other a correctly flat surface is the result. If, however, any of the conditions of accuracy are wanting, then imperfection in the produce will follow as a matter of course. If the lathe is intended to afford screws it must first have a perfect screw within itself to copy from, for if there is any imperfection in the screw copy, or in the divisions of the teeth of the wheels by which it receives collateral motion, the screw produced will contain a transferred copy of each imperfection. It will thus be seen that the lathe is simply a tool to transfer its own character to other things; hence the paramount importance of having the lathe perfect in itself.

Unfortunately, the world, as a rule, does not sufficiently appreciate the difference between perfect tools and tools nearly perfect; but in the government of this portion of the world it is so arranged that those who do not are invariably punished because the want of truth and accuracy entails greater cost in their production, both at the present time and hereafter. To take another notable example—the well-known tool for planing metal—it is a sort of lathe, but differently arranged, and is intended chiefly for the transfer of flat surfaces; it is, however, frequently employed for the production of cylindrical surfaces, or even cones, both figures being obtained on the same principle as in a lathe, namely, by combining, although in a different manner, the straight lines of the machine with the circles of some appendage on the table. As in the lathe, so in the plane, if the latter is not absolutely correct in itself, in all its lines or transferring surfaces, its productions will be imperfect also, and much more costly, if they have to be rectified by hand tools afterwards. The family relationship that subsists between the lathe and the plane is very intimate; neither have much resemblance to their old ancestor, the Aryan potter's wheel, and still less does the lathe resemble its more immediate progenitor, the dead-centre lathe, worked by the alternate motion of a wooden lathe, which has given the family name to its many illustrious descendants.

Another member of the lathe family is the drilling machine. There are other tools of the same family, known by various names, in which the principal motion is given to the cutting instrument. They are variously arranged for movement in any required direction, vertically, horizontally, or otherwise; but the leading feature in all is the copy from which the transfer movement is effected. In another class of tools the required form is embodied in a circular cutting instrument, which is guided unerringly by an iron arm, when the revolving cutter shapes out the reverse of its own form,

as in cutting the teeth of wheels; but the circular cutter may be guided in any other course, regular or irregular, or the article may be simply passed under the cutter, and thereby rendered capable of developing any kind of figure which may by required in the whole range of the arts of construction. In all those tools, and in many others not mentioned, it is wholly a system of copying from a pattern by transfer, and the methods of applying the principle are practically unlimited.

The great lesson to be drawn from the consideration of this principle of transferring from a copy, where the tools merely repeat themselves, and thus become the parent of other tools of the same nature, is this, that the progeny of the said tools have the good or the bad qualities of the parent tool from which it was derived; that if the original tool has not truth inherent in its own structure, whether of true circles, straight lines, or the many other tool virtues, then the tool cannot impart those virtues to other tools, nor is it possible for any real goodness to come out of a bad automatic tool. Hence the importance of having the highest excellence in the innate qualities of the breed; and where it does not exist in the stock naturally then the virtues can only be acquired by reverting to the more primitive class of hand tools. By means of hand labor, combined with extreme care, skill, and patience, the sought-for conditions of truth are ultimately reached, and at a great expense; and the desiderated virtues once acquired and embodied in the automatic tool, will transfer themselves to other tools *ad infinitum*. After copying, the next important point to observe in machine tools is the instruments which men by experience have found the best adapted for treating different materials either by cutting or detrusion, and likewise to note the rate of motion at which the cutting or detruding operations are found to be most efficiently effected. The natural laws which determine the conditions here referred to are not clearly understood at the present time, but there is now an immense number of facts accumulated that point in a particular direction, but have not yet been generalized into laws.

One hundred years ago the cutting of cast iron was a secret which few men could practice. Cast iron appeared to be most obdurate in its resistance to the cutting instrument. From the circumstance that man's past experience had been acquired in the treatment of wood and the softer metals, which admit of high velocity, the earlier attempts to bore and turn cast iron on a large scale failed, because the force was applied in a wrong condition. As experience was gained, it became apparent that a much slower velocity, combined with greater pressure, was necessary, which entirely overcame the difficulty. On one occasion Mr. Bolton, in writing to his partner, James Watt, said, in effect, that the completion of the bore of a cylinder by a new boring bar was most satisfactory; the piston fitted so nicely throughout that there was scarcely room for the insertion of a half-crown at the worst part. In these days of Whitworth tools we can scarcely realise their practical difficulties, which were overcome one by one through the skill and indomitable perseverance of Wilkinson and Murdoch.

The range of velocity found most suitable for different substances lies rather wide; cast iron, for example, requires a slower motion than wrought iron, and may be said to range between 12 to 20 ft. per minute, according to hardness; sandstones, from their structure, require a slower motion in the planing machine when being shaped into blocks or columns; and a slower motion still is found necessary by the Aberdeen granite turner, where the action is detrusion and the edge of the detruding instrument or disc moves in unison with the granite column. Going in the other direction, the limit of speed has scarcely been reached; a velocity of 8500 revolutions per minute is employed in the fine cutting of wood, and even that high speed is not found to heat the instrument to a degree which would necessitate discontinuance of the operation. It is different when the piece of wood itself is driven at that speed, as in the case of woodturning, because from the friction exerted on one point only the temper would soon be taken out of the cutting instrument. The remarkable difference arises from the swift revolution of the cutting instrument, where two new conditions are found to step in. The first is that due

to the extent of the cutting points on the circumference of the instrument, where each point acts in turn, thus giving a momentary rest to all the other points. Then, secondly, from the instrument whirling at such a high velocity, it is in the position of a blowing fan, and is thereby kept cool by the presence of the atmosphere.

There are some other minor points in tools besides those already mentioned which are of great practical importance. When a good tool has been once completed, with all the cardinal virtues, then the question arises, Has it the conditions of surface both in regard to extent and hardness that will enable it to see a reasonable old age and yet retain its original faculties, both in regard to truth and accuracy? Now tools differ greatly in this respect. Some tools make a fair appearance at the outset, but a few years' hard usage seems to take all heart and character out of them, while the properly constructed, sound-surfaced tools retain their excellence for a long period. The materials for tools chiefly consist of cast iron, wrought iron and steel. So far as the toolmaker is concerned in fashioning them into form, the principle of copying by transfer is again the leading feature. A pattern is first made for the founder, which he imbeds in sand or other refractory material. When the pattern is removed the mould or empty space is filled up with the liquid metal, which runs into it by gravity. Beyond this it is almost entirely natural law which the founder has to study and obey in order to obtain good castings, and the founder's practice is chiefly derived from former experience of success or failure, which is just as true philosophy as that which is grounded upon the inductive theory of the thinker, and, as a rule, is equally reliable.

From a number of causes which were in operation during the previous 400 years, chiefly occurring in Italy, France, Germany and England, there begins the gradual dawning of a new era in tools; an entirely new race grew out of the old race, with this wonderful peculiarity and difference, that the idea of mental conception is not merely embodied in the material form, but, in addition, the man's own mental faculties are transmitted to and remain an integral part of the tool. By this change man relieves himself from the drudgery of having again and again to repeat himself. He is not only relieved from the physical toil of using the hammer or the distaff, or other tools, but he saves his mental labor as well. Thus the intellectual thinking of the brain becomes a part of the automatic machine. This second stage of tools embraces the larger portion of modern devices for the treatment of materials, including the mechanism of textile manufactures, and generally, but not necessarily, they derive their force through motors which are independent of man for their effect. It is useless to quote examples in Manchester because they are the leading and distinguishing features of the district for spinning, weaving and working of metals and wood. There is yet a third stage of a still higher order of capacity in tools. There are modern tools which not only have ideas embodied in them like the tools of the second order, but in addition they have what we may almost call a reasoning faculty; they have the capacity of putting several ideas together, then summing up the existing conditions, and arriving at a practical decision in a fraction of a second, a mental process which would occupy a learned philosopher for hours, even if furnished with all the facts of the case. Then there are other tools which are provided with a nervous system, which pervades their mechanism, whereby if any disorder of their normal condition occurs they instantly communicate the fact to a sort of brain and stop of their own accord. Other tools perform the most difficult mathematical calculations, and are capable of printing the result, so that no error may occur in the copying.

When we think of any sort of material beyond the working treatment of their mechanical properties we seem to be in another world. Take, for example, a piece of common wrought iron; it seems to us as of the earth earthy, but if we are closely questioned in regard to the reason for its various properties we find that we scarcely know anything. Tracing it from the ore through its various stages until it is in the hands of the smith is comparatively easy. We know the natural law that governs its elasticity, the limit of its elasticity, its ultimate

strength ; that it can be welded ; that it is ductile and can be drawn out into a fine wire ; that it is malleable and can be spread out into a sheet or work round from the sheet into a goblet, and may be gathered back again, if by so doing it served any useful purpose ; but when we think of the marvellous changes which have taken place amongst its molecules during the operation we are lost in wonderland. To many minds the piece of cold iron seems to be a solid ; under the pressure of the testing machine it is shown to be an unstable fluid. When the smith has the misfortune to leave a piece too long in the fire it vanishes ; it has found evil companions, and gone off under an assumed name and a new character. When a piece of iron is broken and carefully examined under a microscope we can see that it is composed of fine crystals ; but these crystals, we are told, are composed of innumerable molecules, which are not to be seen by the microscope, being smaller than the human mind can imagine; still, the smith feels himself under their influence. In homely words he speaks of the iron being "red-short" or "cold-short," without thinking that he is on the threshold of some of the impenetrable secrets of nature. The steel maker can take advantage of the molecular properties. With heat he can push them asunder and infuse amongst them the subtle vapor of carbon, and the iron becomes steel, highly improved in most of its mechanical properties, and with an increase of strength and elasticity. It may be inferred that each iron molecule is a little world in itself, surrounded with a thin wrapping of infinite space, no single molecule being in actual contact with any other molecule. We have reached the limit of sub-division so far as the engineer dare venture. The investigating philosopher, however, ventures much further with his speculations ; he tries vainly to penetrate into the supposed ultimate atoms of matter of which the molecules are composed, but further we need not follow. Suffice to say that a piece of common wrought iron is altogether a mystery, and teaches man the lesson of humility.

It is an interesting question to consider how the district of Manchester became so celebrated for its tools and machinery. Doubtless there were many causes of a material nature which contributed to the result, but the true cause of Lancashire superiority lies much deeper. As a youth in Manchester, fresh from Scotland, now thirty-six years ago, I was then strongly impressed with a certain marked mental peculiarity, and after spending the interval in a public department, where there was ample opportunity of studying all phases of the working mind of this country, it appears to me that the secret of Lancashire greatness in her own tool specialty is due to the deeply inductive turn of mind which there prevails, and that the inductive habit of mind is the central pivot around which all the other causes that have combined to make Lancashire what it is do revolve. No doubt some of the peculiarities are partly traceable to the line of the Teutonic branch through which they came, their early and inordinate liking for useful work, in combination with a natural inventive faculty, which has now continued for centuries, and grown deep into the nature of the population. Few have had more opportunity of observing the character of workmen than myself, and long since I came to the conclusion that the best practical workmen on the earth's surface are the men of Lancashire. They and their fathers, for more than four generations, have been under a course of training for this pre-eminence. This practical superiority is a consequence of the early introduction of the cotton manufacture among the people of Lancashire—a race who like work for the sake of working—and to the precision required in the making of cotton machinery.

The turn of mind of the genuine Lancashire workman is decidedly practical, and is rarely metaphysical like the Scotch or German. He seldom thinks deductively. His turn of mind leads him from facts to the advanced idea of an improvement, or up to the principle on which the idea is founded. The mind of Watt, for example, was the opposite ; he thought out by a deductive mental process, from speculative principles down to the material idea embodied. This habit of mind, notwithstanding all his marvelous inventive power, would never have made him distinguished in tools, nor

would it have enabled him to achieve the stupendous results that came through the inductive minds of Arkwright, Hargreaves, Crompton, and their successors. Watt arrived at the separate condenser by the reverse process that Arkwright arrived at his great invention. Both are typical of their respective modes of thought, deductive and inductive, from principles down to facts, and from facts up to principles. Watt's mind was full of Black's speculations on latent heat and the radical defects of the Newcomen engine, which he thought out deductively in various directions before the glimpse of a separate condenser came upon him like an inspiration ; even then it was vague and abstract, but, by continuous thinking, it took a concrete form that would afford the practical condenser. Even now the Scotch mind is deductive, and Scotch deduction has to be brayed for years in the English inductive mortar before it becomes great in the class of tools that depend on induction for their contrivance. At the same time Scotch deduction has paid back to England, with compound interest, all that she has received ; many of her sons have become your honored citizens ; and, as engineers, their names are household words wherever the English language is spoken. Even Adam Smith alone, by his deductions on the wealth of nations, has done enough for the trade of Lancashire to entitle him to a niche in the Manchester gallery of fame to the latest posterity. By the foregoing happy combination of circumstances, which acted and reacted on the Lancashire mind for a number of successive generations, Manchester became the cradle of machine tools, and the nursery-ground to grow the men who became the instruments for their development.

From the distinguished position that Manchester occupies as a great tool-making centre it will naturally be expected that everything displayed at the Exhibition here will be the very best of its kind in order to maintain its reputation before the world. The first exhibition of the same nature of which we have any definite account took place between two and three thousand years ago. The class of articles there exhibited consisted of "white, green and blue hangings, fastened with cords of fine linen and purple, to silver rings and pillars of marble; gold and silver bedsteads, with pavements of red, blue, white and black marble." We read that it was kept open for six months, and at the conclusion a grand banquet was given which lasted for seven days; to this feast were invited all the princes and nobles, as well as the people from one hundred and twenty-seven provinces. The wine was supplied from the royal palace, and all drank out of vessels of gold, each goblet being of a different pattern. The official report is contained in the first chapter of the Book of Esther. Although modern exhibitions may not contain such profusion of wealth and magnificence, nor commend themselves to the minds of the æsthetical by having each article of a different pattern, and, therefore, only at the command of the very wealthy, still they contain that which is immensely better, the tools whereby the necessaries and even the luxuries of life are put within the reach of the people generally, who, equally with the rich, can enjoy the comforts and elegancies of civilized life. Such things in a working man's home tend to refine the character, to increase self-respect, and to make this little earth a happier world to live in. Besides, your tools and machinery are not only well-springs of civilization, but still more especially they mitigate the toil of countless millions of the human family. Considered in all their bearings, tools are a mystery; they help to dilute the poison in the sting of the primeval curse, and in some measure to restore to man a small portion of his original birthright.

We understand that the candidates for entry at the various royal dockyards as engineer students have not been very successful in the competitive examination by the Civil Service Commissioners. There were upwards of 100 candidates to fill the vacancies in the dockyards, and of these considerably more than half could not pass the examination. At Chatham Dockyard there were six vacancies to be filled, but it is announced that of the candidates who presented themselves for examination only five succeeded in passing.

—*The Engineer.*

DRY ROT IN TIMBER.*

From "The Building News."

Mr. T. A. Britton has done good service in bringing together into a portable volume all that has hitherto been collected and written respecting that most insidious foe of the builder, Dry Rot. Mr. Britton's experience and facilities have enabled him to avail himself of a fund of varied information relating to the subject. He tells us in his preface "he has availed himself of the assistance of professional friends, builders, timber merchants, foremen, and carpenters," and has been able to record instances of the progress and cure of dry rot. There has been certainly a great deal of mystery as to the origin and cure of dry rot, which Mr. Britton's treatise will help to dispel. The author has consulted also the professional journals of England, America, France, and Germany; and the works of Evelyn, Tredgold, Du Hamel, and other writers who have endeavored to throw light on this stealthy disease have been laid under contribution. The author does not profess to tell us of an unfailing specific that shall arrest and cure the disease, but he places all the known processes before his readers; he gives a fair hearing to every patentee, and adduces many useful instances of the application of simple remedies. Speaking of the origin of dry rot, he refers to a variety of authorities—Pasteur, Baron Liebig, Rondelet, Tredgold, McWilliam, William Chapman, &c. There is a marked difference, we need hardly say, between *wet* and *dry* rots. Wet rot exists only in damp situations. It generally proceeds from access of moisture from without, and may take place before the timber is felled. Dry rot, on the contrary, only attacks dead wood, and the causes which produce it are generally want of ventilation and contact with warmth and moisture. The fungi which attend dry rot, whatever may be their peculiar nature, result from, or are induced by, the conditions necessary for vegetable fermentation. Heat and moisture, no doubt, are the principle conditions required. Sap in a state of fermentation is liable to be attacked by dry rot under certain conditions. The fungus which thrives in this disease differs greatly in appearance, according to the body it lives on. In earth it is fibrous and white, and it may cause some alarm to be told that we might choose a site for our house which is vitally affected with the germs of the disease, and that, do whatever we may in the shape of precautionary measures, by ventilation under our floors, the evil is ineradicable, and that within a few years the house will become a prey to the disease. Such, however appears to be the case, and we know of certain localities in which the dry rot has appeared almost as soon as the buildings were finished. Mr. Britton relates a case. A London builder a few years ago, while building some houses at Hampstead, "found his men were never well; he afterwards ascertained that the ground was affected with rot, and that within one year after the house was erected the basement floor was in a state of premature decay." Sir Robert Smirke also noticed the liability of some situations to attacks of dry rot. Different fungi attack different wood; thus, oak in ships is attacked by a white membraneous fungus, *Polyporus hybrides.* The *Merulius lachrymans* called the dry rot, is one of the formidable enemies of timber. Dr. Greville thus describes it:—"Whole plant generally resupinate, soft, tender; at first very light, cottony, and white. When the veins appear, they are of a fine yellow, orange, or reddish, brown forming irregular folds, most frequently so arranged as to have the appearance of pores, but never like tubes, and distilling, when perfect, drops of water." Hence the term *lachrymans*, or weeping. This fungus is found in cellars and hollow trees. An excess of moisture appears to be inimical to the growth of fungus and dry rot, which rather requires a very moderate degree of dampness, or alternate states of moisture and

* "A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber." By Thomas Allen Britton, late Surveyor to the Metropolitan Board of Works, &c. London: E. and F. N. Spon, 48, Charing-cross.

warmth. Thus in very damp situations, the disease spreads far less rapidly than in dry ones, where the fungus becomes more fibrous, and the timber becomes covered with a brownish white membrane, soft and smooth, which often projects from the surface in white spongeous masses covered with profuse humidity. Certain spots are affected with fungiform protuberances. According to Mr. McWilliam "the fungi arising from oak are generally in clusters of from three to ten ; those from fir timber are mostly in single plants, and these will succeed each other until the wood is quite exhausted." Wooden piles wholly immersed in water have been known to remain sound for over a thousand years, and an instance is recorded of a pile from a bridge on the Danube, which had been submerged 1,500 years. In posts, it is well known by the least experienced, that the rotting or decay takes place at the surface of the ground, or between "wind and water." Beams or joists generally decay first at the surface of the wall, or just within the wall. The ends of timbers are found liable to decay from the same cause. The fact is, wherever there is alternation of dryness and moisture inducing fermentation, the rot is induced, and timber exposed to these influences, or subject to moisture and heat, soon rots.

The use of inferior kinds of timber has contributed largely to the decay of ships and buildings. The firm old English oak (*Quercus robur*) is the least liable to the disease, while the *Quercus sessiliflora*, which is largely used in our dockyards, is sappy, and less dense, and not half so durable. Trenails, by not quite filling the holes, admit water and damp, and Mr. Britton says this is one cause of decay of wooden ships. Mr. Fincham, late principal builder in Chatham Dockyard, says dry rot cannot occur unless air, moisture, and heat are all present, and that the exclusion of any one of these stays the mischief. Ventilation, one of the chief remedies proposed by all authorities on dry rot, should be thorough. For example, the air should be dry to absorb the moisture and carry it off, so that the germs of the disease are not carried to other parts. In ventilating cellars and floors there should be a through current of air between the timbers, and not merely an opening, which would tend to accelerate and increase the growth of the fungus, as air has been known to do in some cases. In an article on this subject, we referred to the absurd practice of buying our timbers instead of allowing them free circulation of the air both at their ends and throughout their length ; thus close-boarded and ceiled floors tend to rot the joists unless the air be admitted on two sides. The author wisely thinks, before admitting air to affected buildings and timbers as a remedy, it is necessary to ascertain its effects, and whether it will not tend to increase the disease. Warmth helps greatly to ferment the vegetable fluids when a certain amount of moisture is present. As to the temperature, Mr. McWilliam, in his work on "Dry Rot," says, at from 50° to 80° dry rot proceeds rapidly, at 90° its progress is slower, at 100° slower still, and at from 100° to 120° it is generally arrested. Many of our readers know the external signs of dry rot, but the following description may be useful to those who do not know the diagnosis :—"Dry rot first makes its appearance as a mildew, or a delicate white vegetation. The next step is a collecting together of the fibres of the vegetation into a more decided form, somewhat like hoar frost, after which it speedily assumes the leathery compact character of the fungus, forming into leaves, spreading rapidly in all directions, and over *all materials*, and frequently ascending the walls to a considerable height, the color variable—white, grayish white and violet, light or decided brown, &c." The italics are ours, as it cannot be too clearly borne in mind that dry rot attacks not timber only, as most people imagine, but brick walls and plastering, stonework, and, in fact, every material exposed to its ravages. We once inspected a brick wall of a dining-room (adjoining another house) which was completely covered with a thin tissue of ramifications like some kinds of fine fern. This appeared over the paper. We advised that the plastering be knocked off, and the wall replastered. Whether the fungus has since shown itself we cannot say. Of course the plant varies with the material from which it derives nu-

triment or support; in some timbers the fungi are more tenacious than others, and different stages of decomposition produce different appearances; some assume all kinds of shapes, from a stem-like growth to a velvety surface. We have before called attention to floor-cloths of an impervious kind as injurious to wooden floors, and we know cases where dry rot has appeared soon after kamptulicon or oil-cloth has beeen laid down. In floors that are either always moist or dry, or subject to alternate conditions, fungus is seldom noticed in the decomposition.

Noticing the use of timber, the author calls attention to the internal rotting often noticed in large beams of yellow fir, which have appeared sound outwardly. This is owing to the use of timber only superficially seasoned. Sawing and then bolting beams has been recommended for this reason; and Tredgold, we believe, first called attention to the desirability of this practice. The effect of dry rot is to cause the timber to shrink lengthways and break, and the part affected somewhat resembles charred wood; if a piece of timber in this state be pressed between the fingers it will crumble to a snuff-like powder. Mr. Britton enters minutely into this part of the subject, through which we cannot follow him. He proceeds to show how incipient rottenness is formed from the removal or sudden disruption of branches close to their roots; and some good lithographic illustrations of the modes of cutting deals, &c., accompany the letter press. Unfortunately dry rot may spread by the germs of the fungi to all parts of a building, besides those affected by actual contact.

Of the kinds of timber liable to dry rot some useful remarks are made—the length of time in the voyage, the condition of the ship's hold, its atmosphere, &c. Canadian yellow pine is more subject to the disease than Baltic or Canadian red timber. Turpentine is a preventive; hence the durability of red timber as a rule. Very few cargoes, we are told, arrive from Canada in which many logs of timber are free from vegetation, or the rot in its first stage. If the cargo has been shipped in a wet state, and the voyage has been long, a white fibre will be seen over all the logs, the yellow deal and Canada pine especially. These facts speak plainly to architects and engineers, and we question whether seventy-five per cent. of the timber used in average building is sound when used. The deals are packed flatwise—no air can circulate round them, and the rot penetrates to a certain depth. Two other kinds of deals are very liable to dry rot—the yellow Petersburg and the Dram battens. White deal is more absorbent of moisture than yellow, and yellow more so than red; hence their more rapid decay in external situations. Some practical remarks on felling timber are given. For hard wood trees like oak and chestnut, sixty years is considered the lowest age, the average age being from 80 to 90 years. A tree of this age produces an average quantity of 75 cubic feet, or a load and a half. Chapter IV. treats of seasoning by natural methods, as hot and cold air, fresh and salt water, vapor, smoke, steam, boiling, charring, and scorching. Immersing timber in running water, and then exposing it to the wind, is a good method for sappy timber. Wheelwrights favor this mode of seasoning. Greater durability, however, is imparted by placing timber in a stream of lime-water 8 or 10 days; it becomes much harder and less exposed to the attacks of worms. This plan is best adopted after the timber is converted into scantlings, as there is then less labor involved.

For joinery, steaming and boiling are considered good methods, as the loss of elasticity and strength is compensated for by a less tendency to shrinkage. These processes are applicable to hard woods, as oak, which requires softening and bending for joinery purposes. An hour of time for every inch of thickness is reckoned as approximate. The author deprecates the use of salt water in seasoning planks by the process of boiling, as they are liable to effects of damp afterwards. Some contend that steaming prevents dry rot; but, as the author observes, low forms of vegetation are very tenacious of life, and it is very doubtful whether this process can destroy the vitality of the ferment spores. The bent planks on a ship's bows are shaped by steaming, and it is said that

this part is seldom or never affected with dry rot. We have therefore some evidence in its favor, and Tredgold says "boiled or steamed timber shrinks less and stands better than that naturally seasoned." Messrs. Davison and Symington's patent process of desiccation is spoken of as being of great value in seasoning floor boards and joinery. It consists in propelling currents of heated air *through* the wood, the heat being regulated according to the kind. The logs or deals are placed in closed chambers or flues of fire-brick, and the heated air, which passes through furnace pipes, is impelled by a fan through the chambers. The process does not char or injure the fibre, as stoving often does, and the vapor is removed as fast as it is expelled from the timber. Timber 9 in. square is the proper size to use. Mr. Bethell's patents are referred to, but the objection to them was that the heat required was too great, and tended to split the wood. A low temperature and long continuance of it are desirable in every desiccating process. Messrs. Holme, builders, of Liverpool, have used the warming apparatus of Messrs. Price & Manby with success, the heat and evaporation being gentle and even; the temperature employed is about 104°. The current of air through the metallic plates draws off the moisture from the timber most thoroughly.

The late Sir Charles Barry employed steaming for drying the wainscot, &c., of the Palace of Westminster—the best Crown Riga wainscot in the logs, and from pipe-staves being used. Smoke-drying is a very ancient mode of preparation. Dryden translates Virgil as follows:

> Of beech the plough-tail and the bending yoke,
> Or softer linden, hardened in the smoke.

The smoke destroys the fungus germ by its bitterness, and smoke from furze or shavings hardens the timber subjected to it. M. Guibert's method is to fill the drying-stove with smoke produced by the distillation of saw-dust, waste tan, smiths' coal, &c. A rotary motion is given to the smoke round the timber. Scorching of charring wood is unquestionably a good preventive of dry rot or decay so long as the inner portions of the timber have been thoroughly seasoned; or else it merely stops evaporation, and expedites decomposition within Mr. Vulliamy, a pupil of the late Sir Charles Barry, the architect of the Metropolitan Board of Works, to whom Mr. Britton dedicates this work, specifies for oak fencing, that the standards shall be filled in and rammed round with dry burnt earth, stones, and burnt clay, and that the "ends in ground are to be well charred before fixing." The charring of wooden posts is not new, being frequently adopted in the country; but the ramming with burnt earth, &c., is not so often seen as it should be. Charred piles last for ages, and the remains of burnt cities, as at Herculaneum, have revealed charred wood quite sound after 2,000 years. The charring of the embedded ends of beams and joists, and those used in warm and moist stables, is recommended. All butting-joints and junctions cut across the grain should be charred. Carbonization, by drying up the fermenting elements, and by arresting the putrefactive process, is at once one of the most valuable and economical means for treating timber we possess as an antidote to decay; and architects, who seldom think of these matters except when necessity compels them, should make it a rule in their specifications. Engineers have adopted the plan for railway sleepers from the first, and with good results. The author truly says that for oak and beech timber, which are hard to impregnate with mineral salts, it is particularly advantageous.

We are surprised the author does not appear favorable to Langton's method of seasoning by extracting the sap by causing a vacuum, or to Barlow's method for the same purpose. The former seems to us one of the most simple means, though it appears to have fallen through to make room for other more elaborate and costly processes.

We have not space left to say much on the careful summary of patent processes for seasoning timber. Our readers are tolerably acquainted with the preservative and seasoning processes introduced by Kyan, Bethell, Burnett and others, so we shall here simply allude to a few facts of value. The two last-named processes, Bethell and Burnett's, have been chiefly employed. Messrs. Bethell and Co. impregnated timber with

copper, zinc, corrosive sublimate, or creosote ; and Dr. Boucherie's process for the injection of wood with the sulphate of copper, seems to have been successful in France, and promises well. Pyrolignite of iron is also used when it is desired to increase the hardness of wood; and chloride of calcium when the wood is desired to be rendered uninflammable and elastic. The process may be applied either when the tree is growing, or after felling ; the preservative salts ascending the branches and impregnating every part. Dr. Boucherie's process aims at preventing not only rot, but increasing the hardness, flexibility and uninflammability of timber, and giving it various enduring colors and odors. We quote Mr. Britton's remarks at the end of the chapter :—" For the professional reader we have three hard facts : the most successful patents may be placed in three classes, and we give the key-note of their success. 1. *One material and one application.* Creosote, petroleum. *Order*—ancient Egyptians, or Bethell's, Burmese. 2. *Two materials and one application.* Chloride of zinc and water ; sulphate of copper and water, corrosive sublimate and water. *Order*—Burnett, Boucherie, Kyan. 3. *Two materials and two applications.* Sulphate of iron and water ; afterwards sulphate of lime and water. Payne." It is also remarked that the only three timber preserving works in London are owned by Messrs. Bethell and Co., Sir F. Burnett and Co., and Messrs. Burt, Boulton and Co.—all B's.

We endorse the opinion that we want a series of experiments on the application of chemicals to wood to resist " burning to pieces " without injuring it otherwise. It may be as well to remind our readers that the ancients were not ignorant of preservative processes. Garlic boiled in vinegar, tar, linseed, palm, and other fixed vegetable oils, especially when mixed with saline matter are preservative, and many of these were used.

One word as to our dwellings and the prevention of dry rot. As we have before remarked in these pages, builders will bed their bond and wall plates in mortar in damp walls, and use putrefactive ingredients instead of sand mortar. What can encourage dry rot so well? Cork or bark has been found to preserve greatly the ends of beams inserted into walls by plates of it wrapped round them. Hot pitch is a good thing to dip the ends of sills and joists into. Allusion is made to " damp courses." Taylor's perforated course, manufactured by the Broomhall Tile Company, is one of the best preventives we know of, as it ensures free ventilation at the same time that it arrests the rising of moisture. Yet our speculative builders heed not. They lay joists on damp brickwork, and stucco, and cover up the face of their walls as soon as possible to stop evaporation. What can be a surer way to dry rot? Sleepers and basement joists should be laid on cement concrete coated with asphalt—the latter material, we think, should completely line the basement of our houses like the copper sheathing of our floating vessels. Unfortunately the correct course in these matters is the one most shirked by the speculator. Thus, to tell him that his building should be left in carcase after it is covered in for some time; that after the plastering is done he should wait till it is thoroughly dry before the floors are laid ; and that painting his woodwork must be avoided, would be to tell him to forego the most valued secrets of his trade. Paint, the great disguiser of imperfect workmanship and rotten, unseasoned materials, is, we are glad to see, strongly condemned ; and wood of different kinds, shades and stains, recommended. Dark and hard woods could be employed for skirtings, stiles, &c., and lighter for the upper framing and moulded parts. Mr. Papworth has shown that paint is a comparatively modern introduction, and that it was not in general use till the time of William and Mary. Mr. Britton justly thinks house-painting was invented by a *bad* builder in the seventeenth century ; and bad builders have been the prolific cause of dry rot and decay. Mr. Britton gives good advice in recommending all who speculate in bricks and mortar to employ an architect or surveyor ; " it is the cheapest course." He categorizes seven classes of bad builders—1st, the ignorant builder ; 2d, the bad builder, who has no money to carry on his business ; 3d, the *partial* scamp ; 4th, the *regular* scamp ; 5th, the *thorough*

scamp; 6th, the "jerry" builder; and 7th, the *vagabond.* We have merely dipped into Mr. Britton's interesting volume, and we have left untouched the chapter on the ravages of the worms and ants. We may, perhaps, again have to notice it, but will simply give here in conclusion the general advice—"Prevention is better than cure" —"season and ventilate." When cure becomes necessary, the author's salutary advice is—Cut out and renew.

THE CORROSION OF BOILERS—ON THE CORROSION OF BOILERS WHEN WORKING IN CONNECTION WITH SURFACE CONDENSERS.*

From "Engineering."

In asking your attention to the subject indicated in the title of this paper, I may premise by stating, that what data I shall have the honor of laying before you, as to the corrosion of boiler plates when generating steam from distilled or redistilled water, will be generally such as has resulted from my personal observation. Much of it will doubtless be familiar enough to those whose professional experience has included the management of boilers whilst working in conjunction with surface condensers. In the earlier days of the practical application of these condensers (I refer to fifteen or sixteen years ago), you must be aware that engineers were often driven to their "wits' end" in striving to account for or to arrest the extraordinary and insidious decay which was steadily and rapidly consuming their boilers before their eyes, while yet there was no recognized means of preventing it. And, indeed, up to the present time, although we have by a primitive, and, withal, a makeshift expedient, been able in great measure to mitigate the evil, I am not aware that the light of scientific research has yet been brought to bear upon the subject with a view to determine the nature or cause of the action itself, or to devise any means of counteracting it.

Fully a decade of years has passed since the writer first endeavored to ventilate this question, by introducing it to the notice of gentlemen whose social and professional positions and interests warranted him in assuming that they would have influenced scientific inquiry in respect of the question. More recently I have tried to set forth the necessity for immediate and decisive action in the matter; but little or nothing of a practically effective nature has been done towards enabling us to grapple with or overcome the difficulty itself. At all events, for aught we have yet learned of the causes of the evil, boilers would decay as surely as they did on its first introduction. My reason for touching so intractable a subject, and pressing it on your notice, is the hope I have that you may add some ray of light towards elucidating the cause of boiler decay, or haply indicate some simple and economic means of arresting it. The subject is, as I think, well worthy of your best attention, since a deteriorating element like that under notice rests like an incumbus on the introduction of what otherwise is an invaluable adjunct to the efficiency of the steam engine.

About a year ago the Board of Admiralty, awaking to the fact that the boilers of the Royal Navy, working in connection with surface condensers, were becoming worn out before their time, and acknowledging the futility of trusting to experience alone to institute a remedy, appointed a "Commission of Inquiry" to take evidence and report on the management and condition of boilers generally throughout the navy. Especially the commissioners were instructed to ascertain the nature and cause of the operations which result in their premature decay, and to report thereupon. This "commission" was composed of one admiral, one captain, two shore engineers, and one chemist—all honorable men,

* Paper read before the Cleveland Iron Trade Foremen's Association, by Wm. Miller.

doubtless; and yet it is scarcely apparent as to what could be the utility of the fighting or navigating element in the commission. It ought to have included among its members at least two marine engineers having practical acquaintance with the management of boilers under steam at sea. These might have introduced or elicited important matters of detail such as would not readily occur to the minds of those who were strange to such duties. As it is, however, they will probably gather some useful information that may lead on to a good result eventually. Twelve months have passed since the labors of this commission commenced, and it was not too much to expect that some report—if only a preliminary one—might by this time have been published. Its appearance might have allured co-workers, equally capable, to their aid. Up to this time it is not visible, however, and we may wait in hope.

The process of surface condensation—by which we absorb the heat from the exhaust steam through bringing it into contact with cold metallic surfaces—although only generally recognized as a practical success within the past fifteen or sixteen years, is a process the original idea of which is to be traced back for a period of well-nigh two centuries. In the mechanical, as in the political or philosophical world, history frequently repeats itself, and seldom has it done so more distinctly than in the case of the surface condenser. So long ago as 1690, Dr. Papin, in one of his experiments made before the Royal Society, after generating steam in a cylinder until it lifted a loaded piston, removed the fire from under it, and allowed the steam to condense by the external temperature of the air, in order to produce the return stroke. About the same time Captain Savery employed the same process and cooled the exterior walls of his gathering vessels with water, in order to create a vacuum for pumping purposes. Contemporary with these we also know that Newcomen, in his earlier attempts to use steam as a motive agent, adopted a similar method to produce a vacuum in his cylinder, until he accidentally discovered that the water injected among the steam was much quicker in its action and better suited to his purpose. We can learn nothing further of the application of the process until the time of Watt, when we find him experimenting with both a "pipe" and a "plate" condenser, either cooled by an artificial air current or by submergence in a running stream, but both of which he ultimately abandoned as impracticable, giving preference to the common injection system. It was not until the year 1832, or about fifty years after Watt's successful adaptation of the "separate" jet condenser, that the true objects of the surface condenser came to be recognized as a desideratum in connection with the steam engine. In that year Mr. Samuel Hall introduced a condenser, consisting of a cast-iron chamber filled with copper tubes through which the steam exhausted, the water at the same time circulating round their outer surfaces. This arrangement met with considerable success, both in the royal and merchant navies. From all accounts it appears to have answered its purpose well; indeed, engineers who have had experience with it, have told the writer that it was all that could be desired. Yet for some reason which has not been sufficiently explained, the system fell into disuse until about 1858, when it was again revived. This time it gained steadily in favor with engineers, and within a year or two quite a host of patent arrangements were in the market. The principal difficulty with the earlier plans was in the making of tight joints between the water and steam chambers—joints that would allow for the expansion and contraction due to the varying temperatures of the tubes. This object has been accomplished by various methods, some employing cotton packing with screwed glands, others compressed wooden ferules, others sheet rubber with gland plates, and others with simple rubber rings of about ¼ inch section, without ferules, glands, or aught but their natural elasticity to keep them in place. I may remark that I consider this latter method to be the best—at once the simplest and cheapest—as, with considerable experience of the more elaborate arrangements I found it to give less trouble, and to be more easily rectified than any other.

The primary object sought after in the introduction of the surface condenser is to secure a supply of pure feed water for the boilers. Were this entirely practi-

cable, we should, after filling our boilers at starting, only require to make good what water we lost from leakage in the boilers, valves or connections, thus keeping the original water doing a continuous round of change—first water, then into steam, then again into water, and so on.

This pure feed supply would insure clean internal heating surfaces, with, of course, a corresponding economy in the fuel consumed ; and in boiler cleaning the former, in the case of steamships, meaning a proportionately smaller bunker and greater cargo or paying space, in some instances no mean item in itself.

With the unquestionable benefits, however, which accompany the system, one very serious evil has arisen, and which considerably mars what otherwise would have been an almost perfect arrangement ; this is, that a certain corrosive action has been found to attach to the internal iron surfaces of all boilers using their feed-water from these condensers ; and so virulent in its character is this action, that what benefits we had expected to accrue from the use of distilled water cannot with impunity be obtained. It is therefore to a description of the nature and extent of this corrosion, with an examination of some of the more probable of the suggested causes and antidotes, that I now invite your attention.

A set of boilers, about four years old, supplying steam of 25 lb. pressure to a pair of engines indicating 900 horse power, and fitted with the common injection condenser, had been under my charge for several months, so that I had every opportunity of ascertaining their internal condition, which generally was as good and clean as could be had in boilers, working under ordinary conditions, with sea-water for feed supply. They had regularly "scaled" at intervals of from 14 to 18 days' steaming, and both tubes and plates were in very fair preservation.

Arriving in England, after having been 15½ days under steam, our old jet condenser was taken out and a new surface condenser fitted in its place. Believing that the distilled water we should in future use would remove what incrustation was on the heating surfaces, I did not go to the trouble or expense of having it removed by manual labor ; but so soon as the alterations were completed, we had our boilers filled with fresh water and started on another voyage. On examining them after 12½ days steaming, we found that the saline deposit left on from the previous voyage had nearly all disappeared from the tube and plate surfaces, and was precipitated on the bottom of the boilers in good-sized flakes of scale. This showed that it had not been dissolved, but that the distilled water had insinuated itself between the scale and the skin of the iron, and so loosened its contact that the ebullition of the water repelled it from the surfaces. The internal surfaces were all as clean as possible, and apparently in perfect condition for the transmission of heat. The only signs of anything fereign to our ordinary experience was the presence of a grayish-colored and almost impalpable powder, which remained in contact with the plates above water-line ; this, however, had no adhesive property, but was readily swept off with a hand-brush.

The color of the tubes and plates also was observed to be much darker than that due to the natural color of new iron ; it was almost black, with a purple tinge about it, nearly resembling that of iron pyrites when denuded of its sulphur. A further examination, after having been another 15¾ days under steam—the while giving excellent results both as to steaming properties and economy in fuel—showed the inner surfaces to be quite clean, with the exception of a dark slimy deposit covering all the under-water surfaces. This, on the moisture evaporating, left as residue a dark brown pulverized substance of a fine sandy nature, but so thinly distributed that at the time we took no further notice of it. Over the water-line was the grayish-colored powder, similar to what we had previously seen, though in greater quantity than before, and specially thick in the vicinity of the uptake plates, but it came off quite as readily as before with a hand-brush, leaving a gray coating, but no incrustation, behind it. Although not again in charge of these boilers at sea, I had an opportunity of examining them after having been under steam during a further period of 33¼ days. The surfaces above and below water had been covered respectively with the gray and dark brown powdery deposit to which we have before referred, but, in addition,

the furnace crowns seemed to be eaten into by some corrosive action, not regularly nor thickly, but here and there, generally in rough blotches measuring from ½ in. to 1 in. across. We concluded at the time that the iron of which the boilers had been made was of an inferior quality, and that the pitted parts were patches of slag or cinder; further experience, however, led us to alter our opinion. Another case, and one which perhaps illustrates even more forcibly the rapid and insidious nature of this corrosive action, was one which was placed under my charge, on being transferred from that already referred to. In this instance both machinery and boilers were entirely new; the former were on the compound principle, and indicated over 1700 horse power, the latter were loaded to 65 lb. per inch.

At starting, our boilers were filled with fresh water, and only distilled water was used for extra feed supply, to recover our loss from leakage, &c.

On the seventh day out, on casually trying the salinometer in the water from the boilers, I found it to denote a density equal to about 2½ times the average density of sea-water; at the same time the water tasted quite fresh, though a little nauseous and greasy. The density steadily increased until the fifteenth day, when the hydrometer denoted a density equal to 17 oz. of saline ingredients to the gallon, or about 3½ times that of sea-water, the water at this time having a greasy-acrid taste, and very nauseous. On examining the boilers we found appearances much the same as previously described. Above water-line was the fine grayish powder clinging to the plates, and under water the dark brown slimy deposit, which, on the water drying up, left the same gritty powder, in color resembling, and which I concluded to be, an oxide of iron. The furnace crowns, and (as we afterwards found) the tubes also, were corroded, and this most erratically—one part of a plate would be quite thickly attacked, while another part of the same plate amounting in area to some square feet, would be left untouched; but generally the action had been most violent in the hotter regions, towards the junction of the furnace crowns and back tube plates. This "pitting" of the iron surfaces occurred sometimes in the smallest hollow specks, and again in large blotches over 1½ in. across, the depth varying from the merest impression to $\frac{1}{16}$ in., the narrower indentations often turning out the deepest; indeed the tubes invariably gave way in little holes from $\frac{1}{16}$ in. to ¼ in. in diameter. After the first voyage we filled the boilers at starting with sea-water, and ceased to use fresh water for surplus feed supply, but the decay still proceeded, though we thought less rapidly than before; and so it continued more or less steadily, until we began to change the water regularly, by blowing off a quantity from the bottom of the boilers, and replacing it by water from the sea, when the decay all but entirely ceased.

Such then is an outline, however imperfect, of the nature and progress of the corrosive action which attacts our boiler plates when working in connection with surface condensers, so far at least as this action has occurred under the immediate observation of the writer. These examples, however, by no means exhibit the extent of this action, as it occurred, in numerous instances; indeed, I know of one set of furnaces that were completely riddled through in their second year, and of a set of iron tubes which lasted only six months and a half, when they had to be taken out and the boilers retubed. Nor are these isolated or exceptional cases either, but the normal experience of all who have had to do with surface condensers in the earlier days of their introduction.

For this malific action there must, however, be some cause, could we but find it out. It is therefore with the object of leading your thoughts in the direction of the true cause that I now proceed briefly to examine some of those which have been suggested as conducing to results such as have been described. It has been with this, as with many other maladies, the nature of whose operations is hidden, or at least is not patent to the external senses, that there has been not a little diversity of opinion with regard to the agency at work in producing them.

Some of these suggested causes are indeed scarcely probable, and may justly be accepted as never having existed beyond the imagination of their originators; as, for instance, a chemical action

arising from the presence of chlorine or hydrochloric acid, said to be in the boilers, though, whence it comes, unless in certain peculiar circumstances, we have not yet been informed. When general attention first became arrested by this corrosive action, one cause suggested—and one which even yet obtains considerable credence—was the presence of an acid, said to be produced by the decomposition of the fatty lubricants passing from the cylinders into the boilers, and acting on the iron as a chemical solvent. No data of which I am aware, has yet ever been adduced in proof of the existence of any deleterious ingredients produced from this source ; until, therefore, something other than mere assertion is brought forward to support the theory, I shall feel bound to dispute its correctness, believing, as I do, that all known facts tend to demonstrate quite the reverse. That this hypothesis has been ill-considered will at once be obvious when we recur to the old style of wagon-shaped marine boilers, generally contracted in steam-space, and consequently much given to priming, into which gallon after gallon of oil was injected to allay the turbid water, and this without ever a sign or sound of any ill effects resulting from its presence. While at all times it is the duty of those in charge of steam-engines to be frugal in the use of tallow in the cylinders, it becomes, when surface condensers are present, a very special duty to minimise the consumption of internal lubricants as much as possible, if only for the sake of the condenser tubes, which are readily fouled and very troublesome to clean. I therefore submit it is more than probable that much less grease will find its way to the boilers under the new than under the old style of condenser. However, with a view to obviate the injurious effects possibly arising from the use of certain, or of any lubricants, experiments were made with various kinds of oil, and in several instances the use of any internal lubricant whatever was entirely suspended ; but these experiments, though invaluable in another way as showing the most suitable oil to use, went to prove nothing of the object for which they were undertaken. Under the writer's observation the decay still continued, where no lubricant whatever entered into contact with the steam, excepting, of course, what little could be carried by the rods through the stuffing boxes.

Another cause was suggested, and one which has of late grown largely into public favor. It is "the presence in the boilers of a galvanic action, induced by particles of brass or copper, which are loosened by attrition from the pipes, pumps, &c, and carried into the boilers by the feed-water." Now, as an exercise to the æsthetic faculties, we could conceive of conditions in which it might just be possible that such an action would be generated, and have the effect claimed for it. Granting that the water became acidulated through the presence of fatty acid held in solution, and granting also that particles of brass or copper could be precipitated over the internal surfaces, we should then have all the elements of an active galvanic battery at the points of contact with these metals, under whose subtle action the iron might slowly pass into solution as a magnetic oxyde.

I, however, would maintain that such favorable and (for the votaries of this theory I may add) favorite conditions do not exist. Firstly, because, this corrosion has occurred where no fatty or other acid could have been present in the water ; even in the densest specimens of the redistilled water, acid was certainly not present to the taste. Secondly, the conditions were unfavorable to magnetic action, inasmuch as the corrosion occurred quite as frequently on the under as on the upper surfaces of the tubes and furnaces, where bodies of the specific gravity due to brass or copper were not likely to be deposited. Thirdly, in the next analysis of the under water deposit (scraped from the corroded parts) the percentage of foreign metals would not warrant us in assuming that these were present in such quantity as could possibly do any harm.

The analysis produced :

Oxyde of iron	77.5
Moisture	19.75
Grease	.85
Sulphate of lime	.8
Oxyde of copper	.6
Traces of alumina, chloride of sodium, and manganese	.5

With the object of diverting from the iron this assumed galvanic action, pieces

of zinc were hung in various parts of the boilers, in the belief that any acid present would, by its affinity for the softer metal, expend its energy on the zinc, and so leave the iron unaffected. I regret that I am not presently in a position to decidedly certify that this plan has made any difference either way with regard to the preservation of the iron, as at the time the zinc was first introduced we were already in possession of other means of arresting the corrosion. I, however, am not inclined to pin my faith upon its value, nor will it unduly establish your faith in the zinc remedy when I tell you that I never once knew its most ardent supporters to try it on its own merits, but invariably in conjunction with a plan which we already knew to be quite successful of itself; yet the zinc, suspended for a few weeks in a boiler evaporating steam from distilled water, will certainly decompose as well as could be wished, and will be taken out an amorphous mass, resembling the "clinker" from a firegrate, considerably increased in bulk, but possessing so little tenacity that it can be crushed between the fingers with no visible element of a metallic nature about it.

Another cause suggested, and the one which the writer believes, and has all along maintained to be the sole cause of this corrosive action, consists in the distilled or redistilled water itself, and in its use for feed supply. I was originally led to form this opinion from a consideration of the facts already laid before you. You will have noted that of the two sets of boilers to which I referred in describing the nature of this action, the decay in former showed itself after a longer interval, and did not proceed so rapidly as in the latter boilers.

While the former were under steam 61½ days before any corrosion was apparent, the latter had only been at work 15 days when they were observed to be more extensively "pitted" than the other. In looking round for some reason why there should be so marked a difference in the rate of progress of this corrosion in these different boilers, I concluded it was due to the cause specified, and for these reasons: first, because in the former boilers the surplus feed had always been taken from the sea, there being no provision on board for distilling it in sufficient quantity, whereas in the latter the deficit was always made up with distilled water only; again, the former bodies were frequently addicted to "priming." When this occurred (owing to the muddy nature of the water carried over into the engines) we shut off the feed pumps from the hot wall, and continued to discharge the water overboard until the boilers had ceased to "prime," these meanwhile being fed from the sea, and thus keeping the water in them more or less impregnated with a saline admixture; while the latter boilers, from their easy steaming properties, were not subject to this evil, the feed being at all times a uniform quantity, only regulated by the demand for steam. The conclusion naturally arrived at by induction from this data was that the extra supply of sea-water becam the saviour of the former boilers, whilst the latter wasted under the influence of the distilled water. The opinion thus formed I have yet had no cause to change; indeed all subsequent observation or imformation has, from my point of view, only tended to confirm it. Extraneous evidence, however, is not wanting in support of this theory (for such many will as yet only admit it to be), but our best hope for its early solution lies in the fact that it is surely growing into general favor. It is a well-known fact that all boilers fed with water from peat-bogs (which water is always nearly pure) do not last so long as those fed with ordinary water, containing a calcic or saline element in solution, while the decay occurs in the same peculiar manner as that induced through working in connection with surface condensers. As an instance of this, I know that some years ago it was a common practice for the locomotives running in the Sheffield district (on the London & North Western Railway), and using the water from the Yorkshire moors, to carry a quantity of carbonate of lime in their tanks, avowedly to neutralize the corrosive action of the pure water on their boiler plates. Another instance—as, I think, peculiarly confirmatory of the distilled water theory—occurred in a sugar refinery in Liverpool, in which four boilers were put down together; two of these sup-

plied steam for heating purposes, which, after circulating between the surfaces until it condensed, was again returned to the boilers as feed water. In this case the water, or steam, was conducted through nothing but cast-iron pipes (so that the galvanic action theory was untenable here), yet, after four year's wear, these two boilers were considered quite unsafe, and required to be extensively repaired, while the other two boilers, supplying steam for the machinery, and regularly fed with the town water, were, after the same term of service, scarcely a whit the worse. In the case of steam-warming apparatus also I have been informed that both boilers and pipes rapidly wear out, and doubtless this will be due to a similar cause. It is a well-established fact that distilled water has a most pernicious action on various metals, especially on lead and iron. Dr. Clark attributes this action to its peculiar property, as compared with ordinary water, of dissolving free carbonic acid.

The chemist Berthier also found that the nodular protuberances commonly seen in cast-iron pipes, when used for conveying distilled water, were composed of these elements:

Analysis of Nodules produced by Distilled Water on Cast Iron.

	per cent.
Protoxyde of iron	21
Peroxyde of iron	58
Carbonic acid	5
Moisture	14.25
Silica	1.33

In view, then, of the corrosive properties evidently possessed by distilled water, I would ask, might it not just be possible that the constituent elements of water, when frequently redistilled, undergo such a change as to greatly intensify its action on, or affinity for, iron? That some change does occur is plainly demonstrated by its very marked and steady increase in density. It is, therefore, with regard to the nature of this change that we so much want information.

A writer in a recent number of *Engineering*, whilst referring to the decay of boilers in the Royal Navy, suggests a course of experiments which must commend itself to all who may have the requisite education and opportunity to conduct them; this is to ascertain what part the influence of heat and pressure plays in modifying the solubility of bodies, with, of course, special reference to iron.

Under the hypothesis that redistilled water is the active agent at work in producing this corrosive action, various methods of neutralizing its effects have been suggested.

One authority suggests the introduction into the boilers of a quantity of silicate of soda or potash; another recommends carbonate of lime; another a mixture of the carbonate and sulphate of lime; while another proposes that the feed-water should be aerated. I am not, however, aware that any of these methods ever advanced much beyond the experimental stage, and some of them—the first and the last—I have never heard of even reaching this length.

The method generally adopted in practice is that of changing the feed-water. In experiments conducted for the purpose of ascertaining the amonnt of extra feed-water required I found that by blowing out a quantity equal to about one-ninth (.117) of that evaporated, and supplying its place with sea-water, I could generally keep a thin scale over the internal surfaces, though occasionally it would only be whitewashed. This changing of the water, however, requires to be done regularly at short intervals, and not hysterically (I found once every four hours to do very well), since, while it is an easy matter to fix a scale, it requires some little care to keep it and keep it thin. Such a scale is easily taken off without "chipping," if not allowed to accumulate in layers, but the tube ends next the combustion chamber—as the part on which the scale most readily gathers—must be carefully kept clean, especially when making steam of high temperature; for, with quite a little incrustation at this part, I have known the contraction caused by the injudicous opening of a tube door to make the whole "back end" of that box leak so badly as to necessitate the shutting off of that boiler, until the tube ends had been subjected to the expander.

Such, then, is the method—I might almost say the only method as yet adopted, successfully to prevent this malific

action. At its best, we must admit it is but a clumsy and a makeshift expedient, only to be tolerated until some better method of protecting our boilers is discovered. It is attended with many obvious disadvantages, not the least of these being that it places in the hands of careless attendants the power of doing serious injury to the boilers, besides interfering with their efficient and economical working. But, apart from all this, such a plan is only avoiding the matter, and is in no way leading us towards any better understanding of the nature of the operations which result in this corrosion, and until we have some definite knowledge of this, we can scarcely expect to devise any remedy that will strike at the root of the evil.

Yet, viewing in the abstract the question at issue, its solution will not appear to be beset with any insurmountable or even very special difficulty, were it made the earnest study of an experienced analytical chemist. The wonder rather is why it has not long ago received the attention it evidently deserved.

A comparison of the constitutents of such water as we know to be suitable for steam boilers with the constitutents of distilled water, and again with those of redistilled water of different densities, would not only greatly enlarge our knowledge of the nature and cause of the peculiar change which I have shown to take place in water during frequent redistillation, but it would probably acquaint us with the nature of such elements as, introduced into the feed-water, might counteract the evil complained of. Of course some difficulty might arise in the practical application of any elaborate chemical process, unless rendered automatic ; but this, as an after consideration, may safely be trusted to the professional acumen of those specially interested in the matter.

One other matter—one strictly correlative to the subject under notice—which invites, I might almost say demands, our attention, is the necessity for the introduction into general use (wherever distilled or other similarly destructive waters are used in boilers) of a hydrometer, or other simple test for quality, one specially suited to the altered conditions of redistilled water, and noting the point, if any, up to which such water can be used innocuously.

Having in the outset of this paper given you my reasons for intruding a rather intractable subject on your time and attention, I trust you will accept those as sufficient, in some measure, to extenuate its choice. I have attempted briefly to trace the history of the surface condenser, from the embryo of two centuries ago, through its various progressive graduations, to the perfect machine of to-day—viewing it as the apparatus in conjunction with which the corrosive action of which we have been speaking was first brought prominently under the observation of all who had to do with them at work. In following sentences I have endeavored to describe the nature and extent of this action, noting by the way such of these incidental appearances and occurrences as are foreign to our normal experience with boilers, when working in connection with the old-fashioned jet condenser, or with high pressure engines, using no condenser whatever.

I have also essayed to point out some of the more probable of the theories which have been formed with regard to the cause of this action, laying before you, as these occur, my personal reasons for assenting to or dissenting from them, and I have presumed further to point out the direction in which I consider their natural solution to be found.

Yet, however positive may be the faith of individuals with regard to the truth or falsity of either of these theories, that they exist in plurality sufficiently proves that in its present state the question cannot generally be accepted as having emerged beyond the region of hypothesis; we still want the weight of acknowledged authority to finally determine the matter from experiment. Towards this end I invite your co-operation in the quest ; I heartily court a full and free discussion of the question on its merits, and I earnestly commend it to the after-consideration and investigation of all who may have opportunity, confident that the complete elucidation of the cause and remedy for this corrosive action will be the certain reward of persevering effort, when we shall have placed within our reach all those benefits which we know must accrue from the use of pure feed-water in our boilers.

THE BAIE VERTE CANAL AND HYDRAULIC HERESIES.

By CLEMENS HERSCHEL, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

I RELUCTANTLY answer the article by Thos. Guerin, C. E., in the January number of this Magazine. Articles and counter-articles of this sort usually consist in the main, of foggy disquisitions upon points of misunderstanding; that the writer did all that in him lay to avoid every misunderstanding, in the first instance, may be gathered from the fact, that long before he thought of writing the paper published in the Transactions of the American Society of Civil Engineers, vol. III., p. 185, he wrote Mr. Guerin a friendly note, intended to draw out a correspondence upon a subject, upon which that gentleman had desired and especially called for comment and criticism. But, inasmuch as the extent of the change of base accomplished by Mr. Guerin between about September, 1874, and January, 1875, is equal to the differential expression of his path, integrated between the limits of Montreal, Canada, and San Francisco, California, it is not to be wondered at that this note was returned to the writer endorsed "Not found" by the P. O. authorities. Circumstances mentioned in the paper then gradually led to its production.

This answer to Mr. Guerin's answer is proposed to be tolerably brief; misunderstandings will right themselves; the profession or the public generally can little care for any personal element that may have been put designedly or inadvertently into the discussion, and the engineers of future tidal canals may safely be trusted to choose for themselves between the articles hitherto mentioned—trusted to reject the conclusions of either or both. To aid them somewhat in this task, it may be proper to point out, however, that having been brought up and trained in a school that incontinently condemns the hashing together in one formula of feet per hour, feet per second, inches per mile, 2240 pound tons per yard (and what not else), but rather elects to have uniformly only a few and simple units of measure (and I trust to live to see the day when even simple feet and pounds shall give way to still simpler metres and kilogrammes), having, as said, been in the habit of expecting only one kind of units, in one and the same formula, I may be pardoned for having overlooked the fact that in the formula $v=n\sqrt[3]{r}$ there was included a rise in feet per hour, a velocity in feet per second and a widely varying coefficient, not a constant. This is mentioned chiefly to explain how the values of n given in my paper were arrived at, all the velocities there, whether vertical or horizontal, being feet per second. How the table on page 56 of this vol. of this Magazine is found is still not clear. For example, if $v=n\sqrt[3]{r}$ certainly when $v = 76.10$ ft. per minute $= 1.302$ ft. per second, and $r=1.612$ ft. per hour, then

$$n=\frac{v}{\sqrt[3]{r}}=\frac{1.302}{1.173} = 1.109, \text{ instead of}$$

0.550 as given, and similarly:

For $v=38.56$ ft. per minute$=0.643$ ft. per second, and $r=0.945$ ft. per hour, it would seem that n should equal 0.655, instead of 1.327 as given, all of which may be noted by future investigators. I take it, there will be no harm done, to quote in this connection, "He should have shown us how he got those figures." But, let Mr. Guerin or the future investigators seriously consider, what shall the profession do with a formula whose main-stay coefficient bobs about, according to Mr. Guerin, from 0.550 to 1.3313, and according to me (as far as I at this time think it worth while to pursue it) from 0.655 to 1.3313?

I desire further to call particular attention to the difference between considering the action of the first flood of water that is allowed to enter and run up on the dry bed of the proposed canal —an event that may happen one, two or three times in a year—and between considering the semi-diurnal action of the tide, in replenishing the amount of water used for locking during the two periods

of 12 hours each of every day, except the above one, two or three, that the canal is in operation. The first seems to have been Mr. Guerin's principal problem and starting point; and if so, then any conclusions drawn from such a mode of consideration, cannot evidently be applied to the action of a canal or estuary that does not run dry at low water. I submit, also, for the consideration of the profession, whether the action of the tide in running up a dry bed of a canal or estuary, and, owing to the "deferlement" or breaking up of the head and succeeding waves, presenting, as it does, the spectacle of a "bore,"—whether the details of such a violent, irregular movement, do not, for the present at least, go beyond the powers of mechanical investigation and formulæ.

The second view of the action of the proposed canal, is one that I have endeavored to investigate, and after careful study of the original books and articles of every one of the authorities quoted in the paper presented to the American Society of Civil Engineers, after experience of my own in constructing works of the class proposed, and after making special experiments to meet the case in hand—in some details an entirely new one, so far as I know—the paper just mentioned was written. It is suggested to Mr. Guerin and to the future investigator, that had he (Mr. Guerin) studied some of the works whose absence he deplores, more especially, perhaps, the works of D'Arcy and Bazin, it is reasonable to presume that his views would have received material modification upon many points. Take, for example, the statement on page 59 of this Magazine, this vol., that "no man of the ability of M. Bazin would state such foolish doctrine." In reply to that it will only be necessary to refer to page 55 and elsewhere of M. Bazin's work, where this doctrine is clearly demonstrated; but then M. Bazin considers the height of the wave itself, and much more of which Mr. Guerin (and he will allow me to say it) evidently has not the faintest conception, never having made a study apparently, of the latest experiments upon waves and wave motion.

Such elements of confusion, as assuming that the present writer is not aware of the distinction and difference between the velocity of the current and, what this same party has termed "the velocity of the beginning of the rise of the water," when the careful wording of this last term, no less than some emphatic remarks about the middle of the 5th page of his paper show quite the contrary; then going to work and battering down this man of straw, thus set up; further, pointing out approximations in formulæ explicitly given as approximate by the name of "errors;" and making merry because these approximate formulæ, though shown by experiments to be reasonably accurate when used between the limits of actual practice, do not, forsooth, apply to the extreme and bootless case of water rushing up the dry bed of a canal; these and similar obstacles in the way of the unwary seeker after truth, need scarcely a pointing out to the careful investigator.

The results of experiments and study, that I submitted to the profession in my paper printed in the Transactions of the American Society of Civil Engineers, as applicable to cases like that of the Baie Verte Canal, are still commended to them for their calm consideration.

In his report, just issued, Major Bolton, the Water Examiner, points out that the contamination of water from the gases generated by sewage is of more frequent occurrence than is generally understood. The gases are extremely liable to flow back into the cisterns and become absorbed by the water, unless the overflow pipe is brought outside the house and the end left exposed to the air, instead of being carried into the drain. The adoption of this plan will effect an object of great importance by getting rid of the poisonous effluvia and gases from the drains which would otherwise ascend through the pipe, and not only be partly absorbed by the water in the cistern but be partly mixed with the air in the houses, thereby becoming a cause of fever and disease. The attention of all householders ought to be given to their cisterns, which should be frequently cleaned out, more especially after periods of flood and turbidity, and every care should be taken to prevent the contamination of the domestic water supply.

ON THE RESISTANCE OF CYLINDERS AND SPHERES—FORMULÆ APPLICABLE TO THE CALCULATION OF HYDRAULIC PRESSES, FOR TUBBING SHAFTS, DAMS, &c.

By V. DWELSHAUVERS-DERY.

From the "Universal Review of Mining."

In his theory of elasticity, Lamé has arrived at exact formulæ relating to the thickness to be given to cylinders and spheres, subjected to regular pressure, in a direction normal to the surface, and uniformly distributed. These formulæ are only applicable to the case in which the strong pressure is on the interior, and the weak on the exterior. They are not adapted to the case in which the strong pressure is on the exterior, and the weak on the interior. Such is, however, the question which arises in the calculation of the thickness to give to tubbing and dams, and one which we consider important to solve.

The method by which Lame arrived at his formulæ is unassailable ; he does not rely upon any hypothesis, and consequently, the correctness of these formulæ may be generally admitted. But this method is so dry, and the digressions are so long, that it seems to us hardly possible that these formulæ, notwithstanding all their exactitude, can ever come into general practice among engineers. England has had the good fortune to see Rankine solve these questions in a much more simple manner, in his work entitled, "A Manual of Applied Mechanics." But Rankine also stops short of the case in which the great pressure is in the interior ; and, in addition to this, his formulæ are not demonstrated by direct reasoning, applicable to the subject alone, but they are rather deduced from more general questions, with which it is necessary to become acquainted beforehand. In my work, entitled, *Principes de la Résistance des Matériaux* ("Principles of the Resistance of Materials"), I have directly demonstrated the formulæ of M. Lamé, by a simple and ingenious method which Captain Devos had shown me for cylinders ; but I also limited myself to the case in which the great pressure was in the interior. When consulted as to the thickness to give a spherical dam supporting a column of water of 150,000 kilogrammes per square metre (213,690 *lb. per square inch*), I was obliged to supply the omission which existed in my *Principes, &c.*, and got out a formula which was exceedingly simple and easy of application, one which deserved, in fact, to be inserted in all engineers' hand-books, in the place of those that are now found there, and which are, it may be said, sometimes misleading.

In applying to great thicknesses the hypothesis that the tension of matter under pressure is uniformly distributed, a serious mistake is made, and one which might prove fatal, especially in the case of dams or tubbing subjected to very great external pressure. One runs a risk, too, in hazarding other hypotheses, however rational they may appear, like those of Brix, for instance. It is evidently better to leave out of the question hypotheses as to the manner in which the tension is distributed, and rather seek to discover, by rational processes, the mode in which this really takes place. By acting thus, we shall be convinced that the co-efficient of resistance, which until now we thought the proper one to be employed, especially in the case of spherical dams, is much lower than the actual tension, as we shall shortly explain.

We will inquire successively in o the four questions relating : 1st, to cylinders subjected to great internal pressure ; 2nd, to cylinders subjected to great external pressure ; 3rd, to spheres subject to great internal pressure ; 4th, to pheres subject to great external pressure.

1st. *Cylinder. Great internal pressure.* —Let figs. 1 and 2 represent a hollow cylinder, closed by two ends of indefinite solidity, enclosing a gas which is capable of exercising a pressure of P kilogrammes per square metre upon all the points of the interior surface, and immersed in a gas exerting, in the contrary direction, and normally to the circumference, a pressure of P′ kilogrammes per square metre. We will suppose $P > P'$.

In its primitive state, the metal of the cylindrical covering is subjected to neither tension nor compression. The effect of the pressure, P, is to increase the internal radius, R, of the annular section (fig. 2), and thus to produce a

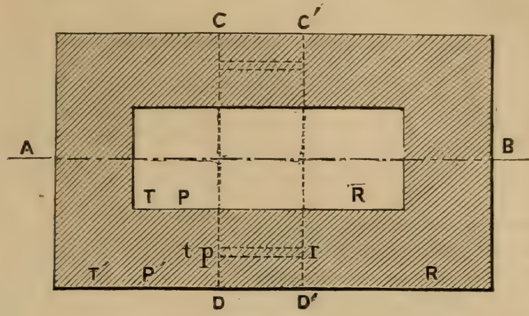


FIG. 1.

tangential tension on the circular fibres, a tension which varies from one fibre to the other, according to the radius, r, of the circular fibre. The pressures, P′, diminish this effect. But these same pressures, normal to the circumference, and in a contrary direction, exercise a second effect, which consists in diminishing the thickness $d\,r$, of the circular fibres, and consequently also, the thickness, $R' - R$. The result is that each one of the circular fibres experiences a certain tangential, or longitudinal tension, which we will call t, for the fibre of any radius, r, varying from R to R′; T for the fibre of the internal radius, R; T′ for that of the external radius, R′. These fibres also experience a transverse compression (at right angles to the preceding) which we will call P, for the fibre of radius, R′; P′ for the external fibre of radius R′, and p, generally, for the fibre of any radius, r.

These tensions are all expressed in kilogrammes per square metre; the dimensions in metres; and we will consider the portion of cylinder comprised between the planes, C D, and C′D′ (fig. 1), to be a metre in length. Under the different influences which we have just mentioned, the cylinder has a tendency to burst asunder in the direction of the plane A B, shown on the first two figures, and comprising the two sections, each a metre long, shown at A A′ and B B′, in fig. 2.

We will now proceed to solve the following question: *Under the conditions which we have just mentioned, what is the longitudinal tension* t, *at any point whatever of the sections* A A′ *and* B B′*? and what is the transverse compression,* p, *at the same point?* We will avail ourselves of this well known property: *when the circumference of a circle of radius,* r *is subject to a normal pressure, regularly distributed, of* p *kilogrammes per unit run, the force of these pressures, taken at right angles to any direction whatever, is* p × 2 r; *that is to say, that it is the same as if the pressure,* p, *exerted itself at right angles to the diameter only.* It follows that this force may be considered as distributed in two equal portions at the extremities of the same diameter.

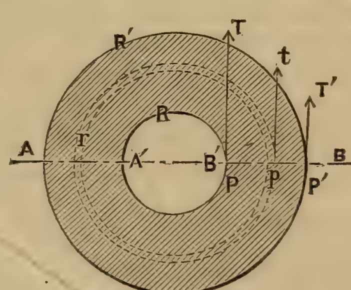


FIG. 2.

This granted, if we consider the fibres comprised between the radii, R and r, the resultant of the longitudinal tensions to which they are subject is equal to

$$P R - p\,r.$$

But inasmuch as t represents their longitudinal tension per square metre of radius run (since we suppose that the line of each fibre is one metre long, taken at right angles to the plane of fig.

2), the tension of a fibre of the thickness, dr, would be $t\,dr$, and the result of the tension, $t\,dr$, which should be equal to $\text{P R} - p r$, will be the sum of the quantities corresponding to $t\,dr$, taken between R and r. We have, then:

$$\text{P R} - p r = \int_{\text{R}}^{r} t\,dr;$$

or,

$$-d\,(p\,r) = t\,d\,r. \qquad (a)$$

To this first relation between p, t, and r, is added a second, by the consideration of the diminution of the thickness of the fibres due to their compression. The compression of a piece of one metre would be $\frac{p}{\text{E}}$, E being the co-efficient of elasticity; the compression of a piece, dr metres in thickness, would, therefore, be $\frac{p}{\text{E}}\,dr$, or, in other words, if the metal be homogeneous, the total diminution of thickness between the radii, R and r, in their primitive state, must be,

$$\frac{1}{\text{E}} \int_{\text{R}}^{r} p\,dr.$$

We can obtain another equal expression of this total diminution of thickness. The original thickness was $r - \text{R}$. Now the circular fibre, the radius of which was originally r, and the length $2\pi r$, has been elongated by $\frac{t}{\text{E}}$ per metre run, and, consequently, by $2\pi r \frac{t}{\text{E}}$ altogether. Its length, at the present time, is, therefore, $2\pi r \left(1 + \frac{t}{\text{E}}\right)$; and as it remains circular, its radius is now $r \left(1 + \frac{t}{\text{E}}\right)$. In the same manner the radius of the fibre, which was originally R, is now $\text{R}\left(1 + \frac{\text{T}}{\text{E}}\right)$. The total thickness, then, which was $r - \text{R}$, in the primitive condition, has now become, after alteration of form,

$$r\left(1 + \frac{t}{\text{E}}\right) - \text{R}\left(1 + \frac{\text{T}}{\text{E}}\right);$$

and, consequently, the diminution of thickness is:

$$\text{R}\frac{\text{T}}{\text{E}} - r\frac{t}{\text{E}} = \frac{1}{\text{E}} \int_{\text{R}}^{r} p\,dr;$$

whence may be deduced:

$$-d\,(t\,r) = p\,d\,r. \qquad (b)$$

Let us develop the fundamental equations (a) and (b), first by adding them member to member, and then subtracting them, when we shall arrive at the results given in the following equations:

$$p\,dr + r\,dp + t\,dr = 0,$$
$$t\,dr + r\,dt + p\,dr = 0.$$
$$dt - dp = 0.$$
$$t - p = \text{const.} = \text{T} - \text{P} = \text{T}' - \text{P}'. \qquad (c)$$
$$2\,(t+p)\,dr + r\,(dt+dp) = 0$$
$$2\,\frac{dr}{r} + \frac{d\,(t+p)}{t+p} = 0$$
$$r^2\,(t+p) = \text{const.} = \text{R}^2\,(\text{T}+\text{P}) = \text{R}'^2\,(\text{T}'+\text{P}'). \qquad (d)$$

From the equations (c) and (d) may be deduced the following:

$$t = \frac{\text{T} - \text{P}}{2} + \frac{\text{R}^2}{r^2} \cdot \frac{\text{T} + \text{P}}{2} \qquad (1)$$

$$p = -\frac{\text{T} - \text{P}}{2} + \frac{\text{R}^2}{r^2} \cdot \frac{\text{T} + \text{P}}{2} \qquad (2)$$

which solve the question.

The diagram of the values of t and p, given in fig. 3, shows clearly how these

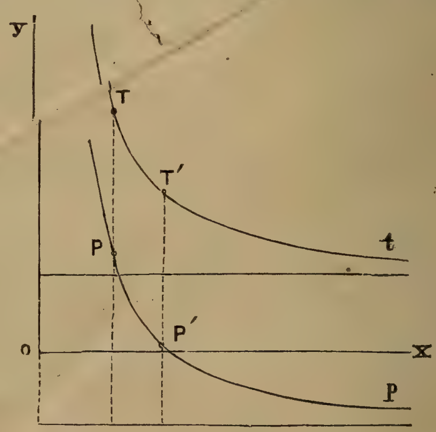


FIG. 3.

qualities vary when the radius varies. The curve (t) is of the hyperbolic class: it has for asymptotes, the axis of the y'

on one side, and on the other a parallel to the axis of the x's, at the height

$$y = \frac{T - P}{2}.$$

The curve (p) is identical with the preceding, but, taken parallel to the axis of the y's at a distance $T - P$ below the former. It has then for asymptotes the axis of the y's, and the straight line

$$y = -\frac{T - P}{2}.$$

It follows that the fibre which is subjected to the greatest strain is that of smallest radius, that is to say, the inner fibre of the radius, R; and its tension is T. This granted, we can solve the following question:

Given: the inner primitive radius, R, *the pressures* P *and* P', *and the limit of tension*, K; *to calculate the radius*, R', *so that it shall not be exceeded at any point.*

From the equations (c) and (d) let us eliminate T', which cannot serve us, and after reduction, and the substitution of the given limit, K, for the tension T, we shall obtain

$$R' = R\sqrt{\frac{K + P}{K - P + 2P'}} \qquad (3)$$

an equation which solves the question, and which proves that no thickness of metal would be sufficient (even if it were infinite) if the pressure, P, were to exceed $K + 2P'$.

If we know the thickness which has been given to the metal in the case in which the cylinder has been able to resist great pressures, we may find, by means of the following equation, what is the true tension, K, borne by the fibre subjected to the greatest strain.

$$K = \frac{P\left(\frac{R'^2}{R^2} + 1\right) - 2P'\frac{R'^2}{R^2}}{\frac{R'^2}{R^2} - 1} \qquad (4)$$

2nd. *Cylinder. Great external pressure.*—Let it be understood that all the previous values are retained. We will not give here all the steps by which we have arrived at the relations (a) and (b); but will only remark that the tension which we before called t was an extension of the fibre; now, however, that it has become a compression instead, it changes its sign. Thus the equation (a) becomes:

$$-d\,(p\,r) = -t\,d\,r$$

$$d\,(p\,r) = t\,d\,r \qquad (a')$$

In the same way the equation (b) becomes

$$d\,(t\,r) = p\,d\,r. \qquad (b')$$

By adding these two equations member to member, we obtain

$$d\,p + d\,t = 0$$

whence

$$p + t = \text{const} = P + T = P' + T' \qquad (c')$$

By subtraction we arrive at:

$$r^2\,(t - p) = R^2\,(T - P) = R'^2\,(T' - P') \qquad (d')$$

Whence may be deduced:

$$t = \frac{T' + P'}{2} + \frac{R'^2}{r^2}\cdot\frac{T' - P'}{2} \qquad (5)$$

$$p = \frac{T' + P'}{2} + \frac{R'^2}{r^2}\cdot\frac{T' - P'}{2} \qquad (6)$$

The two curves, diagrams of the values of t and p, have still for common asymptote the axis of the y's; besides the straight line

$$y = \frac{T' + P'}{2}$$

is also a common asymptote, but the two curves are in symmetrical proportion with respect to this straight line. It will be seen, then (fig. 4), that: 1st, contrary to the preceding case, the transverse compression of the circular fibres continually diminishes from the exterior

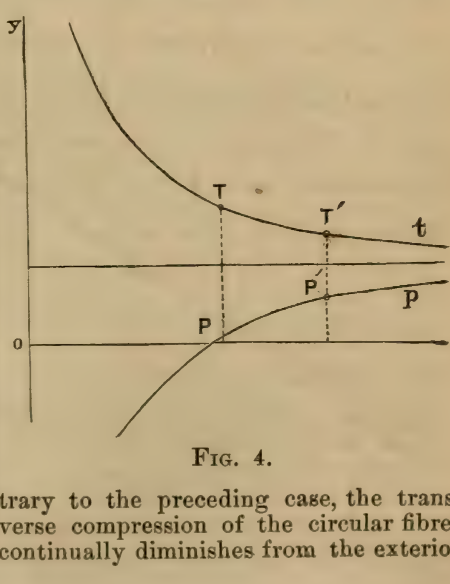


FIG. 4.

to the interior; 2nd, as in the preceding case, the longitudinal compression continually increases from the exterior to the interior. To put a limit, then, to the value K', the longitudinal compression of the fibre subjected to the greatest strain, T must be made $= K'$ in the equations (c') and (d'), and the compression T' must be eliminated from them. We shall then be in a position to solve, without difficulty, the following question:

Given: the external primitive radius R', *the pressures* P' *and* P, *and also the limit of compression* K'; *to calculate the internal radius* R, *so that at no point shall this limit be exceeded.*

Let us remark, in the first place, that the co-efficient of calculation K' may differ greatly from the co-efficient K, admitted for tensile strains. Generally it must be taken at a smaller value, because an alteration of form, begun on the outside, is more likely to be continued up to fracture. However that may be, when we have fixed upon this co-efficient, we shall have:

$$R = R' \sqrt{\frac{K' - 2P' + P}{K' - P}}. \qquad (7)$$

Since P represents a very slight pressure, it follows that the denominator of the fraction, the square root of which is to be extracted, is necessarily positive. As to the numerator, it would become zero if

$$P' = \frac{K' + P}{2}.$$

In this case the internal radius would be zero and therefore the piece solid, thus becoming removed from the conditions of the problem altogether. A higher value would render R imaginary. Consequently, P' is limited to the value $\frac{K' + P}{2}$. *It will be remarked that this limit is considerably lower than that which is obtained in the case of the great pressure in the interior.*

3rd. *Sphere. Great pressure in the interior.*—We retain all the previous values; and the property, to which we before called attention with respect to an arc, is equally suitable to a hemisphere. It follows that the component of the pressures which act upon the interior of the hemisphere is equal to $P \pi R^2$. In the same way, for the sphere of radius r, the component is $p \pi r^2$. The difference $\pi (P R^2 - p r^2)$ is equal to the resultant of the tensions normal to the ring obtained by dividing the sphere in a diametrical plane. Now this tension is $t\,dr$ per linear metre of the fibre, which has a total length of $2 \pi r$; the total tension of this fibre is therefore $2 \pi r t\,dr$. Consequently, we have:

$$\pi (P R^2 - p r^2) = \int_R^r 2 \pi r t\,dr,$$

whence
$$-d(p r^2) = 2 r t\,dr. \qquad (A)$$

As to the second relation, it is the same as in the corresponding case of the cylinder. We have then to deal with the two equations:

$$d(p r^2) + 2 r t\,dr = 0 \qquad (A)$$
$$d(tr) + p\,dr = 0. \qquad (B)$$

The following transpositions lead to the result sought:

$$r^2 dp + 2 p r\,dr + 2 r t\,dr = 0$$
$$r^2 dt + t r\,dr + p r\,dr = 0$$
$$r^2 (dp + dt) + r\,dr\,(p + t) = 0.$$
$$3\frac{dr}{r} + \frac{d\,(p+t)}{p+t} = 0$$

$$r^3 (p+t) = \text{const.} = R^3 (P+T) = R'^3 (P' + T') \qquad (C)$$
$$2\,dt - dp = 0$$
$$2t - p = \text{const.} = 2T - P = 2T' - P' \qquad (D)$$
$$t = \frac{2T - P}{3} + \frac{R^3}{r^3}\frac{T+P}{3} \qquad (8)$$
$$p = -\frac{2T - P}{3} + 2\frac{R^3}{r^3}\frac{T+P}{3} \qquad (9)$$

In fig. 5 are shown the diagrams of the

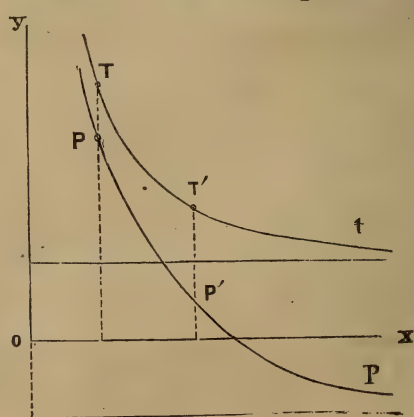


FIG. 5.

values of t and p. These are also hyperbolic curves, having for asymptote the common axis of the y's; each one has, besides, an asymptote parallel to the centre line of the x's at the height

$$y=\frac{2\,T-P}{3}$$

for the first, and a height equal, but of contrary sign, for the second. It will be seen that it is still the fibre of the radius R which is subject to the greatest strain by the expansion. This remark will then serve to solve the following question:

Given: the original internal radius R, *the pressures* P *and* P′ *and also the limit of tension* K; *to calculate the radius* R′, *so that at no point will the tension exceed this limit.*

From the equations (C) and (D) let us eliminate T′, and, after reducing, we shall obtain:

$$R'=R\sqrt[3]{\frac{2\,(T+P)}{2\,T-P+3\,P'}} \qquad (10)$$

It will be seen that if P were to exceed $2\,T+3\,P'$, there would not be sufficient thickness.

4th. *Sphere. Great external pressure.*—The reasoning which enabled us to construct the fundamental equations (a) and (b) applies to the preceding case, and we may be permitted to give the following equations without explanation:

$$d\,(p\,r^2)-2\,r\,t\,d\,r=0 \qquad (A')$$

$$d\,(t\,r)-p\,d\,r=0 \qquad (B')$$

$$r^2\,dp+2\,p\,r\,d\,r-2\,t\,r\,d\,r=0$$

$$r^2\,d\,t+t\,r\,d\,r-p\,r\,d\,r=0$$

$$r^2\,(d\,t-dp)+3\,(t-p)\,r\,d\,r=0$$

$$(C')$$

$$r^3(t-p(=\text{const.}=R^3(T-P)=R'^3\,(T'-P')$$

$$r^2\,(2\,d\,t+dp)=0$$

$$2\,t+p=2\,T+P=2\,T'+P' \qquad (D')$$

$$t=\frac{2\,T'+P'}{3}+\frac{R'^3}{r^3}\cdot\frac{T'-P'}{3} \qquad (11)$$

$$p=\frac{2\,T'+P'}{3}+\frac{R'^3}{r^3}\cdot\frac{T'-P'}{3} \qquad (12)$$

The two curves, diagrams of the values t and p, have also, for common asymptotes, first the axis of the y's, and then the straight line

$$y=\frac{2\,T'+P'}{3}.$$

These are represented by Fig. 6, which

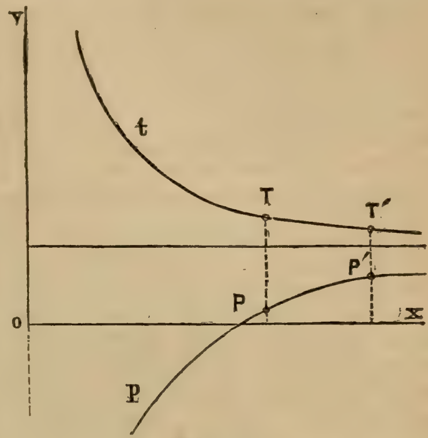


FIG. 6.

proves that the greatest tension, which is here a compression, takes place in the interior, at the smallest radius R. It is, then, also in this case, T, which must be made equal to K′, the safe compressive strain. By eliminating T′ from the equations (C′) and (D′) we shall have the following formula:

$$R=R'\sqrt[3]{\frac{2\,K'+P-3\,P'}{2\,(K'-P)}} \qquad (13)$$

which serves to solve the following problem:

Given: the external radius R′ *and also the external and internal pressures* P′ *and* P; *to calculate* R, *so that tension should at no point exceed the limit* K′.

Since the internal pressure P is small, the denominator $K'-P$ is necessarily positive, therefore the external pressure must be lower than the value which made the numerator negative, that is to say:

$$\frac{2\,K'+P}{3} \qquad (14)$$

If P had the value (13) the internal radius would be zero, and the sphere would no longer fulfil the desired conditions.

Let us now solve the following problem:

Knowing the thickness of a dam which has successfully resisted great pressures,

to find the maximum true tension, T, *which the fibre subjected to the greatest strain has borne.*

From the equation (13) we deduce that:

$$T = \frac{\left(\frac{R'}{R}\right)^3 (3\,P'-P)\ 2\,P}{2\left\{\left(\frac{R'}{R}\right)^3 - 1\right\}} \qquad (15)$$

Application of the preceding formulæ.

Cylinders of slight thickness, but subjected to great internal prsssure.—Under this head may be mentioned: steam pipes, the cylinders of steam engines, steam boilers and their pipes, and gas and water pipes. In the case of boilers, the Government regulations require the application of a formula which supposes the resistance of wrought iron to be $2\frac{1}{2}$ kilogrammes per square millimetre (3555 lb. per square inch), but which contain a constant, to be added for the purpose of covering certain influences not taken into account in the calulation. This formula is therefore, in other words, a purely experimental one. The same may also be said of those which are employed for the calculation of the thickness of steam cylinders, &c., in which one always meets with a constant, determined experimentally. The fact is that this thickness, minimum thickness though it be, should be sufficient not only to resist the pressure of the steam in the cylinder when finished, but also to facilitate the moulding and casting, in order that these operations may be performed both surely and economically. To apply our formula (3) in this case would, then, be superfluous; besides the result would differ but little from that given by the following well-known formula:

$$e = R\frac{P}{K}.$$

In fact, with 0.3 metre (11.81 in.) internal radius and a difference in pressure of 6 atmospheres, taking the resistance as $1\frac{1}{2}$ kilogramme per square millimetre ($2133\frac{1}{2}$ lb. per sq. in.), we find, by the common formula, without constant, e=0.012 m. (.472 in.); and by our formula (3), e=0.0125 metres (492 in.). The difference is too slight to be taken into account, the error committed being imperceptible. But the case, in which the error should be rectified, is, when the great pressure bears a high ratio to the co-efficient of resistance, K; and, consequently also, the thickness of the cylinder bears a high ratio to the radius. This case occurs in hydraulic presses.

Cylinders of great thickness, with great internal pressure.—The above mentioned formula, at which we arrived by supposing that the tension of the circular fibres is uniformly distributed over the whole thickness of the metal, when it is applied to the case of a hydraulic press, might lead to absurd and even dangerous results—absurd, because it induces the supposition that however great may be the pressure, and whatever may be the resistance of the metal, there exists a certain thickness sufficient to prevent the fracture of a vessel; and dangerous, because it gives no information as to the pressure to be taken as the limit that a given metal will bear. The following examples will justify what has been laid down:

Scientific writers admit generally that the *co-efficient of resistance* of cast iron to tensile strain, is 600 kilogrammes per square centimetre (8534 lb. per square inch), and that, in practice, the co-efficient of calculation should be equal to the co-efficient of resistance divided by a co-efficient of safety, which should never be less than unity. However, in the case of hydraulic presses, 600 is admitted as a suitable figure for resistance in calculating the thickness. Now let us admit that the given internal pressure, P, be also 600 kilogrammes per square centimetre, and that the internal radius, R, of the press be 0.15 metre (5.9 inch). The above formula will give:

$$e = 0.15^{m} \times \frac{600}{600} = 0.15^{m}$$

$$R' = R + e = 0.3^{m} = 2\,R.$$

As the exterior pressure, P′, is about 1 kilogramme per square centimetre (14.2 lb. per square inch), while P = 600 kilogrammes per square centimetre (8534 lb. per square inch), we will omit P′ from our calculations, in the presence of P, and make use of the following formulæ in place of (3) and (4).

$$R' = R\sqrt{\frac{K + P}{K - P}} \qquad (3)\text{A}$$

$$K = P \frac{\left(\frac{R'}{R}\right)^2 + 1}{\left(\frac{R'}{R}\right)^2 - 1} \qquad (4) A$$

If in the preceding case we make $R' = 2R$, let us see what, in reality, is the tension of the inner ring of the press. The formula (4) A gives :

$$K = 600 \frac{4+1}{4-1} = 1000.$$

The inner fibre, then, that is subject to the greatest strain, undergoes a tension which might be considered dangerous in reality, and which must consequently receive an appreciable permanent alteration.

In accordance with the formula (3) A, if we were to make $K = P$, we should find R' infinite. But if we have been able to construct presses, which have actually borne, without injurious result, a tension of 1000 kilogrammes per square centimetre (14223.36 lb. per square inch), let us admit that this co-efficient may be employed in our formulæ, and let us see what we shall arrive at in the case in which the pressure, P, though less than 1000 kilogrammes per square millimetre, exceeds 600 ; for instance, let us make $P = 800$, and let us calculate R' by the two methods :

Ours gives—

$R' = 0.45$ metre $= 1.47$ ft., and $e = 0.3$ metre $= 11.81$ in.

The other—

$R' = 0.35$ metre $= 1.14$ ft., and $e = 0.2$ metre $= 7.87$ in. But if the latter thickness be adopted, the internal tension would be 1160 kilogrammes per square centimetre (about 16.499 lb. per square inch), a strain which the cast iron could not bear with safety.

For a pressure of 900 kilogrammes per square centimetre (12801.02 lb. per square inch), our formula would give $e = 0.504$ metre (1.65 ft.) ; and the other, $e = 0.225$ metre (8.85 in.) ; by adopting this last formula, we should find that the actual maximum tension is 1243 kilogrammes per square centimetre (17,679.63 lb. per square inch).

Cylinders of slight thickness, with great external pressure.—Boiler tubes, used as flues, come under this category. If the external pressure be not great, the difference between the results of the formula

$$e = R' \frac{P' - P}{K' + P' - P}$$

usually employed, and that, (7), which we have demonstrated, is not worth while taking into consideration in practice. Thus, for $P' - P = 6$, and $K = 200$, we find, by the foregoing formula,

$$e = 0.029\ R',$$

and by ours,

$$e = 0.031\ R',$$

giving a difference of only a few decimals of a millimetre, in the case of tubes of 0.6 metre (nearly 2 ft.) in diameter. It is no longer the same, however, when the pressure bears a considerable proportion to the resistance, as we shall proceed to show.

Cylinders of considerable thickness, and with great external pressure.—This case occurs in the tubbing to shafts, especially when the pressure of water is great. Supposing that the strain is uniformly distributed over the whole thickness, we arrive at the formula :

$$R' = R \frac{K' - P}{K' - P'}$$

R' and P' being the radii and the external pressures. Our method gives the following :

$$R' = R' \sqrt{\frac{K' - P}{K' - 2P' + P}}.$$

The internal pressure, P, is that of the atmosphere. We will suppose it to be 10,000 kilogrammes per square metre (14.223 lb. per square inch).

It seems that we can apply the first of these formulæ to the calculation of the thickness of tubbing, by making :

	Kilogrammes per square metre.		Lb. per square inch.	
$K' =$	120,000	=	170.68	for brick.
$K' =$	450,000	=	640.05	for oak.
$K' =$	800,000	=	1137.86	for stone.
$K' =$	4,000,000	=	5689.34	for cast iron.

Now the limit of the value of P' will be K', in accordance with the first formula, and $\frac{K' + P'}{2}$ in accordance with the second. If, then, we estimate the pressure, P', in respect to the height of water, we shall have for limit of height of the

column of water pressing on the tubbing:

	Brick.	Oak.	Stone.	Cast Iron.
In accordance with the first formula.....	120	450	800	4000 met.
	393.7	1476.4	2624.7	13123.5 ft.
In accordance with the second formula.	65	230	405	2005 met.
	213.2	754.6	1328.7	6578.2 ft.

So long as the pressure of water does not approach these limits, it is a matter of indifference which formula be employed; but this is by no means the case when the limits are approached, as the following table will show. Having calculated the value $\frac{R'}{R}$ for the brick, the oak, and the stone, for a column of 60 metres (196.85 ft.); then for the oak and stone, for a column of 200 metres (656.17 ft.); and lastly, for the stone, in the case of a column of 350 metres (1148.31 ft.), we obtain:

	Bricks.	Oak.	Stone.	Oak.	Stone.	Stone.
Value of H.............	Metres. 60	Metres. 60	Metres. 60	Metres. 200	Metres. 200	Metres. 350
$\frac{R'}{R}$ according to 1st formula.	1.833	1.1283	1.0675	1.76	1.3167	1.7556
$\frac{R'}{R}$ according to 2d formula.	3.31	1.1376	1.07	2.707	1.388	2.68

Thicknesses for $R=1\frac{1}{2}$ *metre.*

	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
According to 1st formula..	1.25	0.192	0.101	1.14	0.475	1.133
According to 2d formula...	3.465	0.206	0.105	2.561	0.582	2.520

Thicknesses for $R=4$ *metres.*

	Metres.	Metres.	Metres.	Metres.	Metres.	Metres.
According to 1st formula..	3.333	0.513	0.270	3.040	1.267	3.022
According to 2d formula...	9.240	0.551	0.280	6.828	1.552	6.720

If we adopt the thicknesses given by the first formula, we shall be in a position to calculate the true value of K', according to the second formula. This value of K' is independent of the value of R, and depends only upon the ratio adopted for $\frac{R'}{R}$. We shall have, then:

True value of the maximum Tension.

Kilogrammes per square metre.

153,000 | 480,000 | 830,000 | 571,000 | 908,000 | 1,018,000

Lb. per square inch.

217.61 | 682.72 | 1180.53 | 812.15 | 1291.48 | 1447.9

It will be found preferable, in the case of very deep shafts, to make use of cast iron. If, for instance, the tubbing be subject to the pressure of a column of water of the height of 800 metres (2624.71 ft.), by taking K' as representing 4,000,000 kilogrammes per square metre, we shall have:

In accordance with the first formula,

$$\frac{R'}{R} = 1.247$$

In accordance with the second formula,

$$\frac{R'}{R} = 1.287$$

For $R = 1\frac{1}{2}$ metre (4.92 ft.), the thickness would be, in accordance with the first formula, 0.37 metre (1.21 ft.), and, in accordance with the second, 0.43 metre (1.41 ft.).

The maximum tension to which

cast iron is subjected, if we calculate the ratio $\frac{R'}{R}$ in accordance with the first formula, comes out so high as 4,437,000 kilogrammes per square metre (6310.9 lb. per square inch), a figure which we must regard as too high. However, it must be admitted that a thickness of cast iron as great as 0.43 (1.41 ft.) is excessive, and the cost of such tubbing would be unusually high. Besides, in practice, a higher co-efficient of calculation than 4,000,000 has been employed. As a matter of fact, in the Carling Pit, a thickness of only 0.045 metre (1.771 in.) has been given to a cast-iron tubbing of the radius of 1.68 metre (about 5 ft. 6 in.), and that at a depth of about 165 metres (541.34 ft.). We have, then, in this case—

$$\frac{R'}{R} = \frac{1.725}{1.680} = 1.02678$$

$$\left(\frac{R'}{R}\right)^2 = 1.054277$$

$$\frac{P'}{P} = 16.5$$

and, in accordance with the second formula—

$$K' = 6,031,444.$$

Now if, in the preceding example, we were to give to K' this value we should find, in accordance with the second formula, that—

$$\frac{R'}{R} = 1.1644$$

whence $R' = 1.747$ metre (5.731 ft.)

and $e = 0.247$ metre (9.724 in.)

a thickness which is still very great, but which, at the same time, it would be dangerous to diminish, when the pressure is so enormous.

Hollow sphere, of considerable thickness, with great external pressure.—Spherical or Saxon dams come under this head.

When it may be supposed that the tension is regularly distributed over the whole surface, we arrive at the following formula :

$$R' = R\sqrt{\frac{K'}{K' - P'}} \qquad (a)$$

in accordance with which the limit of pressure will be equal to K'. Our formula (13) gives :

$$R' = R\sqrt[3]{\frac{2(K' - P)}{2K' - 3P' + P}} \qquad (b)$$

which proves that the limit of pressure is—

$$\frac{2K' + P}{3} \qquad (e)$$

The limits in height, therefore, of the columns of water would be :

	Brick.	Oak.	Stone.
In accordance with (*a*), in metres................	120	450	800
In accordance with, equivalent in feet..........	393.7	1476.4	2624.7
In accordance with (*c*), in metres................	83	303	537
In accordance with, equivalent in feet..........	272.3	994.1	1761.8

An oak dam, subject to a pressure of 240 metres (787.41 ft.) of water, and the inner radius of which was $R = 7$ metres (nearly 23 ft.) should, therefore, have a thickness :

In accordance with formula (*a*),

$$\frac{R'}{R} = 1.4637 \qquad e = 3.246 \text{ metres.}$$

In accordance with formula (*b*),

$$\frac{R'}{R} = 1.6663 \qquad e = 4.664 \text{ metres.}$$

If we make the thickness 1.7 metre (5.577 ft.), we shall find, in accordance with formula (15), that the maximum pressure may be as high as 730,000 kilogrammes per square metre (1038.29 lb. per square inch).

The thickness of a spherical wood dam, constructed in Saxony, to resist a column of water, 200 metres (656.17 ft.) high, with an inner radius of 6½ metres (21.325 ft.), was 1.883 metre (6.177 ft.).

It follows that the maximum tension, calculated by formula (15), is, in this case :

$K' = 543,500$ kilogrammes per square metre (773.03 lb. per square inch.)

These examples are sufficient to show that engineers are by no means agreed as to the co-efficients of safety, to be employed in calculations respecting works of this kind ; and that, generally, the tension to which such structures are actually subject is greater than was supposed.

EXPRESSION IN ARCHITECTURE.

From "The Building News."

It is not unusual to hear a person exclaim, "How heavy that building is, or how light! it is more fit for a prison, or it has the look of a music-hall." Such opinions comes from those who are perfectly ignorant of what architecture is, as well as from others critically conversant with the art. However unintelligible the language of architecture may be to the uninitiated, these outer forms of expression are well understood by the majority of them at least. In our times, however, a kind of spurious expression is admitted. Thus we hear of such-and-such a building spoken of as having too much of the club-house character, or as being too like a church, simply from the association accidentally attached to those structures. An able writer on design has well stated this fallacy of confounding the few causes of expression in architecture with association. The ideas of expression which the uninitiated majority—and, indeed, all who are capable of perceiving distinctions—have are totally different from the ideas which a sentimental study of art invokes. These last are based really on a very superficial study of a few examples without going any deeper. The writer alluded to says "It is most important for all who attempt to practice or understand this art to be perpetually on their guard against the insidious attacks of this error, the mistaking (*i. e., acquired*) expression for that which is natural, and therefore permanently true. I cannot but consider this the chief source of the acknowledged great utility of travel to the architect. Its use is not to show him much of the world, but to teach him how little of it he has seen. Nothing but the emancipation from narrow local prejudice will set a man thinking and searching in earnest to distinguish what is local and accidental, in beauty and expression, from what is universal and essential." Just now there seems to be a greater prevalence of this false estimate of design, and architects and writers generally appear to fall into the same mistake in distinguishing buildings. It is a species of hypercriticism that has become the bane of *soi-disant* critics, and some amateurs. It smacks of a meagre acquaintance with a few examples, instead of a generalized study of all styles. Thus the first adverse critics indulged in lampooning porticoes to churches *because* they were first used in front of heathen temples, as another set stigmatized the earlier works of the Gothicists forasmuch as they recalled mediæval superstition. It was not uncommon for the critics of forty years ago to apply all sorts of pseudonyms and sobriquets to any buildings that savored too much of some typical or well-known example, as if the resemblance detracted from the merit of the composition as a whole. To be brief, we must spurn this kind of comparison if we are to benefit at all in an age essentially electric like the present. What matters if a building is adorned with a cupola too much like those which crown the facade of Wilkins's National Gallery? They may look "pepper-casters" upon the aforesaid structure, but it would be unwise, as well as foolish, to denounce the adaptation or even copy of one of them as too much like a pepper-box if it suitably met the conditions of a new structure. To apply this kind of stricture is not at all to the point, however clever and smart it may appear. Unfortunately art-writers are a little too much addicted to the "sensational," too fond of conjuring up likenesses, however far-fetched, and flavoring their remarks with illustrations and analogies that unfortunately often cut as much one way as another. There is one excuse for this, however: it is an easy way of dealing with a dislike when more substantial reasons cannot be adduced. Architectural or art disquisitions would be sometimes a little wearisome, and too much like theological subtleties for the easy digestion of most people, if examples were not given; but let them, at least, be well chosen. Architectural expressions, then, are considerably narrowed when we have struck out these spurious ones—in fact, they cannot for a moment be considered so numerons as the multitudinous wants of

all our buildings—that is to say, it would be absurd to suppose there was an expression suitable to each kind of building. If our domestic buildings are sometimes like convents, and occasionally like club-houses, there is nothing to complain of, for individual tastes are equally as diverse. Neither should we be so fastidious as to censure the proclivities of church-builders, who in one instance embodied the extremest sacrificial type of plan, and in another the congregational auditorium. These are differences for which there are ample apologies to be found, and yet in both cases our ideas of true art expression would be shocked if these extreme religionists carried their tenets so far into the fabrics as to violate what would be considered to be proper architectural adaptations in plan or external features. Thus it is possible to admit a certain degree of diversity into our designs, even if we appear to trespass upon the character of other buildings so long as we confine ourselves to justifiable expressions.

Let us here consider for a moment the range of these architectural expressions, and how far we may make them intelligible. Mr. Fergusson, in his "Essay on the principles of Beauty in Art," divides the arts into five classes : the technic, as carpentry ; the technic and æsthetic, as plain architecture and gastronomy ; the technic, æsthetic, and phonetic, as sculpture ; the æsthetic and phonetic, as poetry ; and the phonetic simply, as rhetoric. This ingenious classification embraces all the arts. To the highest class of architecture this author awards equal proportions of the three merits—that is to say, of technic or mechanical merits ; æsthetic or those giving pleasure ; and phonetic, those capable of telling a tale. But the author says this is only the case when architecture *per se* is connected with sculpture or painting, and the Greek architecture is selected as fulfilling this condition. As justly observed by Mr. Garbett, the system, however ingenious, fails to show in what respect the architect is superior to the picture-frame maker or the cook, and the same writer points to an intermediate kind of expressiveness in architecture—one that is capable of doing more than simply please by exciting different emotions, and yet incapable of speech. This kind of "dumb expression," as he terms it, is common to all the fine arts ; we see it in architecture as well as in instrumental music. It is a language common to all the arts of form and sound—it appeals to everybody alike, there can be no ambiguity about it. The pyramids and Temples of Egypt convey an impression that cannot be mistaken of one extreme kind, while the ærial fancies of the Arabs or the cunning artifice of the Hindoo palace or temple are equally apparent in awakening a different impression. Thus, after looking at the ruins of Karnac, with their massive forms based upon the square and circle, a sense of majesty or solemnity steals over us ; not like the impression felt upon viewing a mediæval cathedral or that awakened by the splendid remains at Delhi. One over-awes by its mass, the other captivates. But we may illustrate three or four well distinguishable expressions of great historic periods. There are those represented by Thebes, Athens, Rome, and mediæval Europe, all well marked—that is, the impressions or feelings they are calculated to convey or arouse apart, from association, are readily defined in language. Thus awe in the first, majestic repose in the second, grandeur and sumptuousness in the third, and aspiration in the fourth are well understood sensations, which none but the most deadened to art influences can fail to have experienced. If we inquire we should find the greatest ignoramus was influenced by those works of architecture in the same or nearly in the same degree as the educated, showing that associations have nothing whatever to do with these broad and simple forms of expression. But let us next inquire into some of the sources of these various effects. Unfortunately there have been various deadening influences, such as association and the indiscriminate employment of different styles as the fashion of the day leads, which have dulled our perceptions ; and so, if a gentleman wishes to build a country residence, any of the styles or expressions we have indicated may be used just as well as any other, regardless of the occupant's tastes and feelings' and at variance with the scenery. Expression is not studied by the architect, because his pet style is adopted and carried out

in accordance with his own idea—that is to say, if a regular-featured Classic kind of exterior was best adapted it would be ten to one rejected for a broken picturesque house; and, where irregularity of outline and sharp contrasting features would be a charm, a regular or placid-looking edifice would be designed. Now, the true avocation of an artist, rightly so called, and we presume every architect believes himself to be one, is an ability to convey an impression—not any sort, but the right one in the right place—just as he may use his pencil in conveying an expression of countenance or giving a clear idea of a portrait or a group of figures by a few well-understood touches. Above all things an artist, like a rhetorician, should be enabled to convey an impression in the shortest way. He should make the study of form and color or sound, in their various effects upon the eye or ear and, through it, to the sympathies and feelings, the great one; he, in fact, should become a physician in the art of allaying and soothing and giving pleasure or excitement to the emotions, or of swaying them in a pleasing manner. If he cannot do this he is no artist, and if he prescribes the wrong style he is unskillful, if not an impostor. The alphabet of expression consists of but a few characters. We have rectangular forms, or those in which the horizontal lines are continuous, and the vertical discontinuous, as in the Greek styles of composition. "A severe purity reigns supreme." Such an expression may be found in the Grecian Doric, and it appeals to the soberer qualities of the mind. In the Roman and Palladian we find a milder repose. The vertical features are more prominent and less massive, and circular and angular features break the extreme simplicity of the Greek composition. Under Scamozzi and the Venetian artists we find the curved or circular forms breaking still more into the severe rectangular treatment of the Greeks, as in the Vandramini Palace, Venice. Here the voids encroach largely upon the solids or walls, and if we study the Venetian palaces we shall find the arcade and the fenestration as conspicuous as the solid portions. In the court of the Ducal Palace, and in the earlier semi-Renaissance, a playful picturesqueness prevails. In the first building the introduction of the arch and the panelling of the piers gave a light and playful expression to the facades, and this is increased by the admixture of semi-circular and pointed arcades. Again, we have an inviting and extremely elegant expression in the Palladian style, as we see it in the Barbarano Palace, at Vicenza, and in the arcaded fronts of the Vicentine basilica. The superimposed orders, so favorite a treatment of Palladio, eminently suggest a festive and domestic expression—one admirably fitted for civic and palatial purposes no less than for buildings destined for music and the drama. Now, in both these extreme expressions of the Classic school, a repose though of different degrees prevails, the features and architectural lines all partaking of a contrast, rather of gradation than of suddenness. The angles, for instance, are generally right angles or obtuse ones, suggesting ideas of sublimity and repose rather than energy and unrest, as in the Pointed styles. In the latter the forms are more angular, the lines meet at sharper angles, indicating rigidity and energy; thus the vertical features of buttresses and shafts rise uninterruptedly; no horizontal members disconnect them or stop them, as we find in the column and entablature of the Classic orders; the buttresses spring beyond the bounding lines of the building and terminate in pinnacles, and these converge in their turn to points. Again, in the pointed windows and the spire the same piercing energy or character is seen; their angular apices and points indicate an upward growth—a dynamic rather than static condition: the whole composition, indeed, of such an edifice as Salisbury or Amiens Cathedral is one suggesting energy and force, not repose. We may briefly enumerate a few of the abstract principles upon which architectural expression depends. Alison and other writers on the subject have agreed upon certain kinds of form which suggest ideas to the mind. Thus angular forms and lines express strength, energy, and force; the same qualities produce strong contrasts of light and shade on surfaces, and these sharp transitions characterize rocky scenery and Gothic buildings. The contrary

kinds of form—those that are curvilinear and winding, and which give rise to gradation of light and shade—indicate delicacy, ease, grace, and refinement, and characterize the Italian modes of Classic treatment. The Greek character, as seen in the Greek Doric, shows a combination of these opposite forms: we get the square and circular forms combined as in the Doric order. In the Roman styles the curvilinear and rectilinear are equally blended, producing grandeur and richness of expression; and in the Gothic forms they are again united, though the angular forms are predominant. In one extreme we have contrast, expressive of grandeur, force, and exciting qualities, and in the other extreme of gradation, elegant and soothing qualities. The architect should be master of these combinations, and be able to apply such varieties of form as will best conduce to a particular expression. Unlike painters and sculptors, architects are the professors of abstract design, and, as we have said, should be able to discover the general laws of expression in the same manner as the physicist does with inert matter. Another principle well worth noticing is the proportion of opening to solid wall in our buildings; and we dwell upon it here as it has scarcely been noticed by other writers. We have styles in which the wall is everything, and others in which the openings dominate over the design. In the Greek, the openings were merely apertures compared with the wall; but in the Venetian Italian it becomes a framework only—so extreme is the difference. In the Early Gothic the windows are mere piercings and slits in the walls; but in the Latter Gothic—the Perpendicular, for instance—they occupy by far the largest area, the wall spaces being reduced to attenuated piers or mullions. This principle is indiscriminately applied by architects, as we see in churches. In one, we find all windows in the clerestories and aisles, in another, all wall space. It is generally an excess of one or the other that is to be condemned. If the admission of light had anything to do with it we would not complain; some architects prefer "a dim religious light," and to this they conform their design. But the principle has a great deal to do with expression also; a windowless building like Newgate prison has a forbidding expression, a repelling character not unsuited in that case; but a building full of windows has an inviting cheerful aspect no one can mistake. The Italian schools illustrate not only the formal principles of expression we have enumerated, but this one of lighting also. Thus, in the Florentine, there is scarcely any arcuation, though the style is astylar; windows bear a small proportion to the wall space, while, in the Venetian schools, arcuated effects are largely used, and the window is an important feature. The Roman holds a kind of intermediate ground between these two. In the Florentine we have almost Doric simplicity and severity in the structural features; in the Roman a more varied treatment; and in the Venetian highly broken lines, large windows, and picturesque features. As an English style for country residences, and when ample light and cheerful expression are wanted, the Venetian is best suited, and it has been largely adopted by the English architects of the Renaissance; for town and civic structures, in which a severer expression is required, the Florentine or the Roman is better adapted. In the Gothic styles we have quite as large a range to choose from. Of course, in regard to windows, lighting must always be mainly regarded, though these may be expressed variously, and the architect may always give his buildings their own suitable expressions by selecting the proper formal element of those we have referred to.

AIR-SHIP FOR MAIL SERVICE.—A German inventor, Mr. William F. Schroeder, of Baltimore, is said to have submitted to the New York Engineers' Association a model of an air-ship, designed for carrying the mails between America and Europe. The air-ship is to be steered by a hydraulic apparatus of eight horse-power, and to be carried by a gas balloon. The ship weighs 2,800 lb., and has a carrying capacity of 12,000 lb.; its minimum rate of progress is estimated at seventy miles an hour. Experiments are now being made with it: should they be successful, a proposal will be made to Congress to intrust the mail service to air-ships.

TEST OF HOWARD BOILERS AT THE FAIR OF THE AMERICAN INSTITUTE.

By THERON SKEEL.

I.

Sir : The Committee appointed by the Managers of the American Institute Fair for the test of the Howard Boilers, on exhibition there, beg leave to inform you of the details of the test decided upon as follows :

The test will commence on the afternoon of the 17th, and will last twenty-four hours.

Anthracite coal of good quality will be furnished by the Institute in sufficient quantity. The weight of coal consumed by the boiler will be noted as nearly as possible as it is fed into the furnace.

The ashes and refuse will be weighed dry.

The boiler will be fed by an injector with cold feed water from a tank, and the volume noted half hourly.

During the first twelve hours the steam will be maintained as nearly as possible at 250 lbs. pressure per square inch, and during the latter twelve hours at 75 lbs. per square inch above the atmosphere.

The temperature of the steam will be noted by a mercurial thermometer in the steam drum or near it.

A portion of the steam, probably about 10% will be condensed in a worm surrounded by cold water, and the weight and temperature of the steam so condensed together with the weight and temperature of the condensing water at injection and discharge will be noted. These measurements will give the means of computing accurately the amount of priming, or the degree of superheating of the steam so condensed. It will be *assumed* that the balance of the steam which will be allowed to escape from the safety valve is of the same quality.

The temperature of gas in the chimney will be measured by a thermometer in a sand bath placed in it.

The boiler will be fed by an injector, the water being maintained as nearly as possible at the same level. If practicable, a *steady feed* shall be kept on the boiler.

You will be at liberty to select your own firemen, and to have control of the fire during the experiment, provided the Committee do not wish to replace them by their own men, it being distinctly understood that the Committee reserve the right to assume control of the fires at any moment when they should think proper to do so.

It is the wish of the Committee to leave the charge of the fires entirely in your hands, and they will only interfere if they consider the uniformity of the experiment is being injured by very irregular firing.

The rate of combustion will be, if possible, 12 lbs. of coal per square foot of grate per hour or greater.

The keeping of the log of the experiment will be done by the Committee or their assistants.

The Committee would like to have you send them tracings of the boiler and the manner of setting, and of such details as you may think proper, in order that they may compute the grate surface, heating surface and calorimeter, and notice the peculiarities in their report. They would be glad to receive these tracings at once.

The second boiler from the south end has been selected for trial, because it is near the chimney and has the ordinary form of grate.

The connections of the other boilers with the flue will be closed during the experiment.

The Committee will expect to receive notice from you that you are satisfied with these conditions before commencing the experiments.—Very respectfully,

Theron Skeel,
Judge, Group I., Div. V., for the Committee.

JUDGES' REPORT.

New York, Feb. 5, 1875.

To the Board of Managers :

Gentlemen,—After full and impartial examination of the Howard Sectional

Safety Boiler the undersigned Judges make report that there were two kinds of boilers exhibited by this company, the one being set in brick-work and provided with grates, feed and blow-pipes, safety valve and all appurtenances ready for use, and that this boiler was used to provide steam for warming the building and running the machinery during the time the fair was open ; the other being only a few sections of tubes not set in brick-work, but intended for exhibition only. Your committee understand that this last pattern was the form of boiler now manufactured by the exhibitors, being a recent improvement since the others were set up in the fair, and feel themselves at liberty to consider this last form as entitled to the award, although the experiments for economy and efficiency were made on the older pattern.

The following description applies to both forms of boiler :

The water and steam are contained, as in most of the class to which it belongs, *within* wrought iron tubes while the products of combustion are in contact with the outside.

The original motive, no doubt, for introducing the class of boiler was to obtain the necessary strength to resist the high pressure of steam now coming into almost universal use, without resorting to very thick shells.

The forms generally used previous to the introduction of sectional boilers were for stationary purposes, cylindrical shells containing either tubes or flues, set in brick-work and absorbing heat both from the outside through the shell and on the inside through the tubes or flues ; and for marine purposes, of an iron shell having an appropriately rectangular section and containing several furnaces and sets of either fire or water tubes. These forms of marine boilers have now generally been superceded by those having cylindrical shells of large diameter containing several cylindrical furnaces and a sufficient number of horizontal fire tubes.

Notwithstanding such boilers are in general use they have many disadvantages and are probably soon destined to be supplanted by another form.

The stationary boilers have been in part supplanted by the Howard and other forms of sectional boilers, and your committee are encouraged to make a careful report on the Howard boilers in the exhibition by the facts that there is a large demand for the best boiler of that class, and that the results of the experiments and examination may assist both the manufacturers and the consumers.

The following excellent description from a technical journal applies to the later form of Howard boiler :

"As will be seen from the views we give the boiler is like the former Howard boiler, composed of wrought iron tubes 9″ in diameter externally, these tubes being connected together in groups, and being placed at a slight angle with the horizontal, several tubes of each group lying one over the other."* It will be remembered that in the horizontal tube boilers, until lately made by Messrs. Howard, the several tubes of each group are connected by one end only.

"In the new type, however, connections are provided at both ends, a decidedly better arrangement. Referring to the engravings and particularly to the detailed cuts it will be seen that each tube has fixed to it at each end a cast iron cap or chamber. The manner in which these caps are fixed to the tubes is somewhat peculiar. Around each tube at each end is placed a thin wrought iron hoop and holes are punched through this hoop, and the body of the tube. The tube end, properly cleaned, is then placed in the mould and the cast iron cap cast upon it, the metal running through the punched holes as shown in Fig. 1."

"To perfect the joint the wrought iron hoop, which as shown, projects slightly beyond the casting, is calked all round the tube. Messrs. Howard assure us that these joints stand well and give no trouble. The mode of attachment is certainly a simple one, and the introduction of the wrought iron calking strip is ingenious."

"To connect the superimposed pipes forming each section, the end caps or chambers are provided with nozzles turned slightly conical externally, these nozzles entering wrought iron junction rings bored out conically to receive them. The arrangement is shown clearly in the upper part of Fig. 1. From which it

* ("Engineering," July 24, 1874.)

will be seen that the nipples on the cast iron cap take their bearing entirely against the conical surface of the wrought iron junction rings, and do not butt against each other. * * * * * The series of caps are drawn tightly together by a

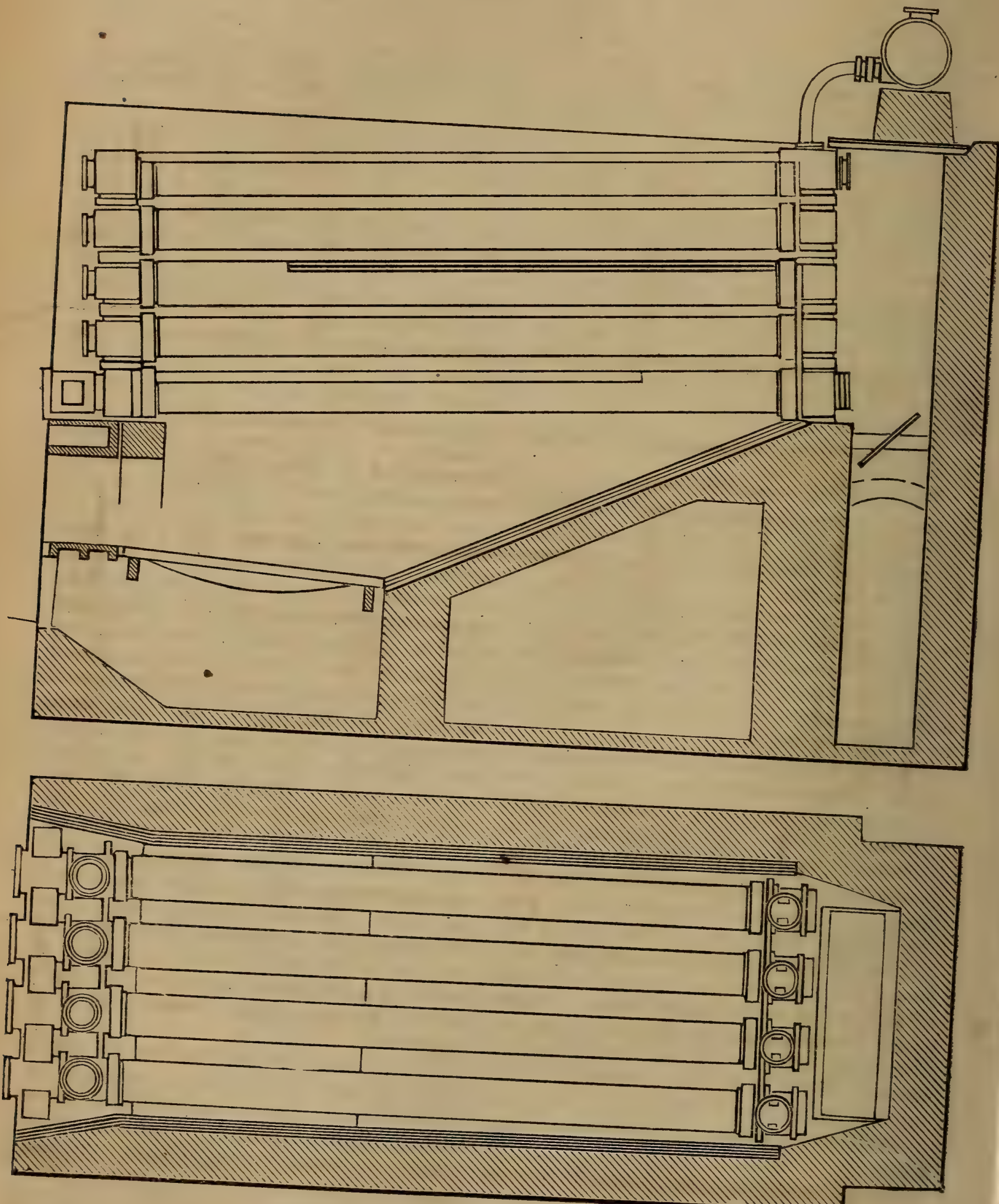


FIG. A.

pair of internal bolts at each end of each section, these bolts which are of rectangular sections, lying close to the sides of the caps, and being furnished at their

lower ends with ⊥ heads, which take hold of lugs cast inside the lowest caps, as shown in Figure 1 of the detail views. * * * * * On the outside of the caps are cast square flanges and ribs for holding fire bricks or tiles for

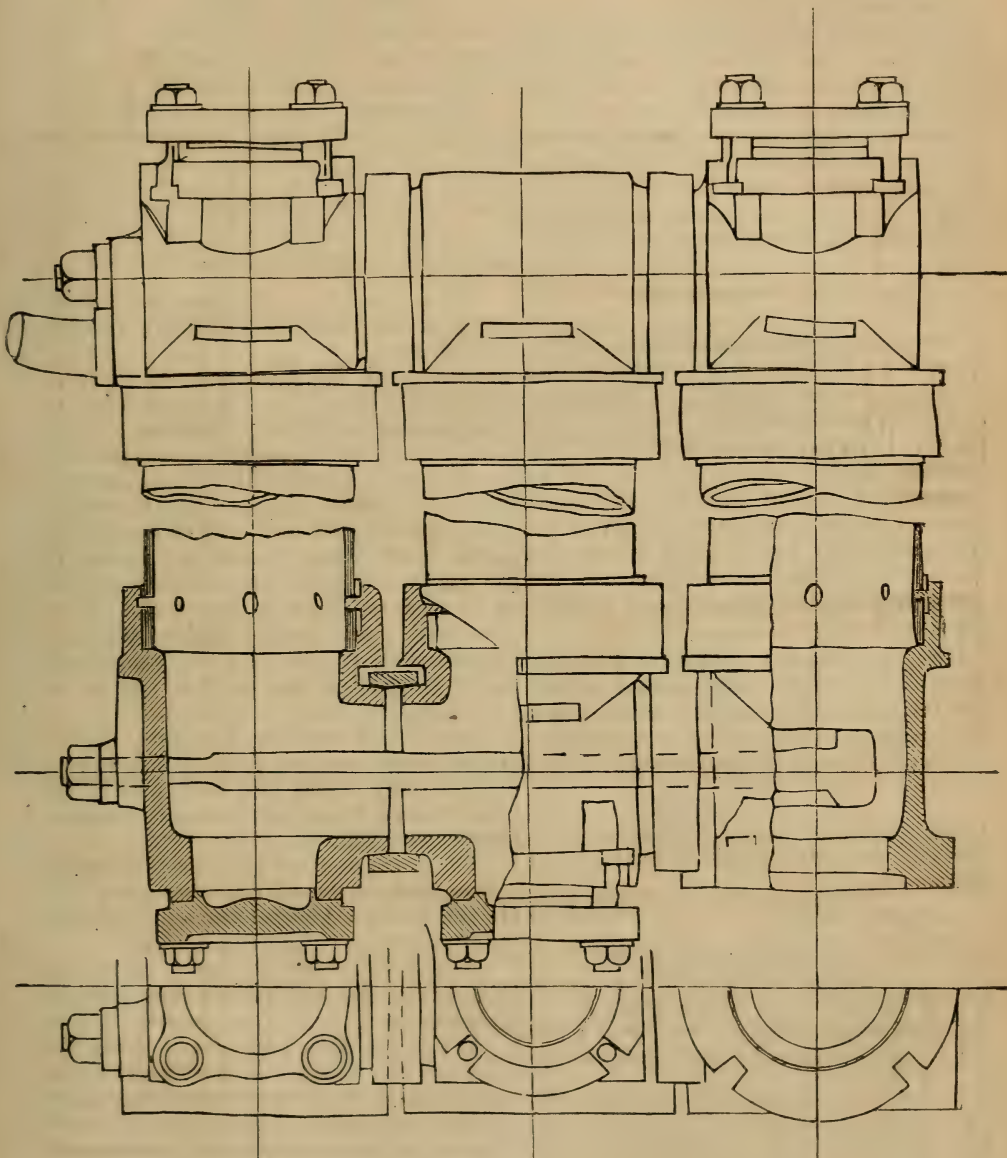


Fig. 1.

closing up the spaces between the sections."

"The arrangement of the setting of the boiler will be readily understood from the general views (Fig. A), from which it will be seen that the steam is led off through curved pipes from the higher end of the section to a steam drum."

In the boiler which was used during the fair, the inclined tubes were connected at one end only with wrought iron vertical tubes by screwed joints. The

openings between the tubes are in some places closed by iron plates laid upon them, causing the products of combustion to take the tortuous course indicated by the arrows.

The opening from the furnace to the flue is closed, except at the top, by a brick wall, thus preventing any of the hot gas passing directly into the flue without going between the tubes.

The opening into the chamber containing the nests of pipes is closed at the front end by cast iron plates, each plate being long enough to reach from top to bottom, and about 6″ wide. These plates are locked together and held in place by suitably arranged lugs. By taking down these plates, each of which could be easily handled by one man, the whole exterior surface of the tubes could be inspected and cleaned and by removing the caps to the heads, each of which was held in place by one bolt; the whole interior surface of the tube could be cleaned. The feed water is introduced into the lowest horizontal section at the front, and may find its way into any of the tubes in this horizontal section, but can only reach the upper tubes through the back end.

The following are the principal dimensions of each of the four sections of boilers on exhibition, each of which could have been used separately or in conjunction with the others by suitably arranged valves:

Grate surface, 27 □′
Heating do. 593 □′ ratio to grate, 22 : 1
Superheating
surface, 294 □′ " " 10.9 : 1
Cross area of passage for products of combustion between
the grate bars, 10 □′ ratio to grate, 1 : 2.7
1st connection 1.9 □′ " " 1 : 14.1
2d do. 6.7 □′ " " 1 : 4
3d do. 3. □′ " " 1 : 9
into flue
(original) 3 □′ " " 1 : 9
into flue
(reduced) 1.25 □ " " 1 : 21.6
steam room,
128 cubic ft. ratio to grate, 4.7 : 1
water room,
74 cubic ft. ratio to grate, 2.7 : 1
lbs. of water in boiler at two gauges, 4200
mean area of smoke stack,
4.36 □′ ratio to grate 1 : 62
height of smoke stack above grate, 60′
surface of boiler exposed to radiant heat of fuel, 45 □′
mean distance from top of fire, 2.′6″
distance traveled by product of combustion while in contact with tubes, 34′
diameter and thickness of tubes, 9—5/16″
length of tubes, 12′
diameter and thickness of steam drum, 12″—1″
length of steam drum, 6′

The arrangement of these sections in reference to the flue and chimney is shown in Fig. 6.

One section No. 3 was selected for trial.

It was decided by the committee to test the capacity and economy of the boiler under two steam pressures in order to determine whether there was any difference in the working. These tests took place on the 17th and 18th of December, 1874, the first being under a pressure of 75 lbs. by the gauge, and continuing from 7.30 p. m. on the 17th until 5.30 a. m. on the 18th; the second being under a pressure of 135 lbs. by the gauge, and continuing from then until 4.30 p. m. on the 18th.

Before commencing the first experiment steam was got up in the boiler to 75 lbs. with wood and coal, which was then drawn from the furnace and carried from the room.

The grate and ash-pit were then swept clean, and 46 lbs. of dry pine wood laid in the furnace, kindled and supplied with coal as fast as it could be ignited.

At the time the wood was kindled in the grate the experiment was held to commence.

While the fires were drawn from the furnace the height of the water in the glass gauge was marked, and was maintained as nearly as possible at this height during both experiments, and was brought there after the fires were drawn at the end of each.

The coal was weighed out in lots of 300 lbs. each, and as fast as required, a fresh lot being laid upon the floor as soon as the last one was all upon the fire. The lbs. of coal entered upon the log are those recorded by the man at the scales,

thus at 9.30 p. m, when there is marked 1800 lbs. of coal, 1500 lbs. of this may have been on the fire and 300 lbs. on the floor.

It was intended to fire often and as regularly as possible. As much coal as the fire required was fed on about every fifteen minutes. The draft was not good and the fires were worked a great deal with the slice-bar, and a great deal of fine coal forced through the grates into the ash-pit by the efforts of the fireman to force the fires. The kind of grate used, the "Tupper bar," dividing the grate into small openings, $\frac{1}{2}'' \times 1\frac{1}{2}''$, with an intermediate rib $\frac{1}{2}''$ thick, did not allow the fires to be pricked up from below. It is believed that if this could have been done a considerable more active combustion could have been maintained.

The fires were thoroughly cleaned at 3.30 a. m. on the 18th, after having been in use nine hours. The total refuse for the first ten hours was 373 lbs., or about 15 per cent. of the coal probably consumed during that period.

The fires were maintained at a uniform thickness of from 7 to 9 inches.

The coal was "Lackawanna" of apparently good quality and was in uniform lumps of nearly 3″ greatest dimension.

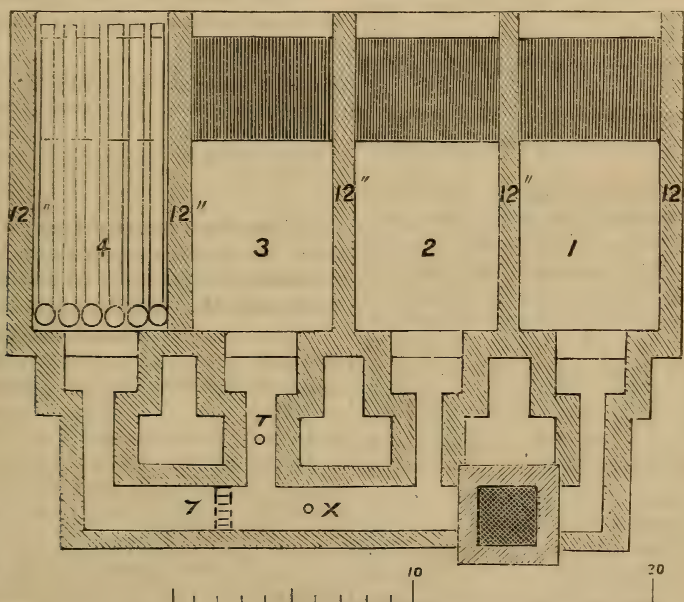


Fig. 6.

It was fed to the fire without being picked, directly as it comes from the coal yard.

The ashes and clinker, and all the material remaining on the grate at the end of the experiment, were weighed while dry and deducted from the weight of coal fed in. The balance being charged as "*combustible.*"

The feed water was fed into the boiler by an injector from a wooden tank on one side of the fire-room. This tank was 14′ $0\frac{1}{2}''$ long by 5′ $10\frac{1}{4}''$ wide, and 7 ft. deep.

A brass rod divided into inches and tenths, was arranged to slide vertically in a socket screwed fast to the side of the tank. This rod was provided at its lower end with a hook, which formed a little dimple in the surface of the water whenever the point was a little above or below. By moving the rod slowly up and down, and by watching the appearance, disappearance and reappearance of this little dimple, the point of the hook could be adjusted as accurately to the surface as the review on the socket would read — $\frac{1}{100}$ of an inch.

The weight of water corresponding to one inch of depth of the tank was 317

lbs. nearly, so that the weight of water which had been fed into the tank was able to be measured within $3\frac{1}{100}$ lbs. at any instant.

The gauge was adjusted to the surface of the water, clamped and read every half hour, and at the expiration of the half hour was read again in its original position before being readjusted to the lower level.

The tank was so large as only to need to be replenished once during the whole time.

It was intended to keep a steady feed on the boiler, but the injector would not feed so slowly and had to be shut off about $\frac{2}{3}$ of the time. The tank was mounted on blocks two feet above the ground, so that its whole surface was visible.

It was practically tight, the leakage not exceeding 50 lbs. during the whole trial.

In place of condensing all the steam that was formed in the boiler in a surface condenser, and measuring the weight of water so condensed together with the weight of the condensing water and the corresponding temperatures, as was done by the Committee in 1871,* the following plan was adopted. It is believed this method was first suggested by J. D. Van Buren, Jr., C. E., late Engineer Corps, U. S. N., Assistant Engineering Department of Docks, New York: A small portion of the steam was drawn from the steam drum in the neighborhood of the safety valve, and conducted through 25 ft. of $1\frac{1}{2}''$ pipe to a worm on a tank of water. This pipe was carefully wrapped with felt $1\frac{1}{2}''$ in. thick, and was provided with a valve at the end near the steam drum, by which the amount of steam flowing to the worm was regulated. There was also a valve on the outlet from the worm. The worm consisted of 32 pieces of $1\frac{1}{2}$ pipe each $30''$ long, and connected together to form a rectangular spiral, the whole coil being immersed in the water. A short pipe was led from the end of the worm through the side of the tank, and delivered into a barrel placed on scales close by. Condensing water was led into the tank at the top from the croton main through a pipe provided with a valve to regulate the flow.

This water discharged itself through an orifice in the bottom of the tank into a waste pipe leading to the sewer. The tank was the same that had been used for the rotary engine test at the Fair, and for the test on the circulating pumps on the U. S. S. "Tennessee," by Chief Engineer Shock, U. S. N. The amount of water which would be discharged by this orifice at various heads had been found by previous experiments on the "Tennessee." The following is an extract from the report on that occasion :*

"The following are the mean results of 49 experiments with a head greater than three feet :

Head of water above plate, in inches.	Cubic feet discharged by each orifice per sec'd.
72.154	.1059
52.660	.0900
41.050	.0796

"Fifty-four experiments on less heads than these gave results varying among themselves from zero to twenty-five per cent., and are therefore rejected.

"The amount of water discharged from the same orifice at different heads should vary, if there were no causes of disturbance, as the square root of the heads.

"The following comparison of the amount discharged actually and computed for the last two cases, by a comparison of the square root of the heads with the amount delivered in the first case, shows that the discharge does vary as the square root of the head, as the differences are within the errors of observation :

Head in inches.	Discharge by Experiment.	By Comparison.
72.154	.1059	———
52.660	.0900	.09019
41.050	.0796	.07964

"The co-efficient of contraction being the ratio of volume of water actually discharged to that represented by the area of the orifice multiplied by the theoretical velocity, is"

$$C = .7766.$$

* See Rep. Com. of Boiler Test. Am. Inst. Trans., 1871.

* Reports of trial of circulating pumps on U. S. S. "Tennessee," 1874.

Number of Cubic Feet which will be Discharged in One Hour from a Single Orifice at Various Heads, computed from Experiment by a Comparison of the Square Root of the Heads.

Head in inches.	Discharge.	Head in inches.	Discharge.
72	380.8	52	323.7
71	378.2	51	320.6
70	375.5	50	317.4
69	372.8	49	314.2
68	370.1	48	311.0
67	367.4	47	307.8
66	364.6	46	304.5
65	361.9	45	301.1
64	359.1	44	297.7
63	356.2	43	294.3
62	353.5	42	290.9
61	350.6	41	287.4
60	347.7	40	284.0
59	344.8	39	280.3
58	341.8	38	276.7
57	338.8	37	273.1
56	335.9	36	269.3
55	333.0	35	265.6
54	329.9	34	261.7
53	326.8	33	257.9
52	323.7	32	254.5

The tank was of boiler iron 48″ diameter and 72″ deep, and ⅜ thick.

Soon after starting fires in the boiler the steam was turned into the worm and the croton water into the tank.

The valve in the croton water pipe was adjusted so as to supply as much water as would flow through the orifice under a head of 56½ inches, and was not changed until the experiment was concluded on the following day. It was intended to adjust it so that the head of water would be 60″, but the variation of level was so slow when there was nearly an equilibrium established between the inlet and the discharge that after it was supposed there was an equilibrium, that is when there was no visible variation of level and the valve made fast, the surface of the water sank slowly during the next hour from 60″ to 56½″, as recorded in the log. The croton water was drawn from the main in 2d Avenue.

As the orifice in the bottom delivered a uniformly varying quantity proportional to the square root of the head of water in the tank, and as there was a constant area of opening in the croton water supply pipe during the whole experiment, if there was any variation of head in the tank it must have been from a variation of pressure in the croton main.

The pressure in the main undoubtedly does vary at different hours of the day with the consumption of water.

The head of water in the tank indicates that the pressure was greatest from 3 a. m. until 5 a. m., and was least from 8.30 until 9.30 a. m.

The consumption undoubtedly varies in the inverse. The following table shows the variation of pressure as indicated by this experiment at different hours during the day. This variation is only true for the section supplied by the main at *this season.*

Hour.	Pressure.	Hour.	Pressure.
9.30 P.M.	94.1	7.30 A.M.	95.
10.30 "	94.1	8.30 "	83.3
11.30 "	96.7	9.30 "	90
12.30 A.M.	96.7	10.30 "	91 7
1.30 "	98.3	11.30 "	93.3
2.30 "	98.3	12.30 "	93.3
3.30 "	100	1.30 P.M.	93.3
4.30 "	100	2.30 "	93.3
5.30 "	100	3.30 "	93.3
6.30 "	95		

These figures indicate that the consumption commences to increase after 5.30 in the morning and rises rapidly to a maximum at 8.30. From 8.30 it diminishes slowly until 11, after which it remains nearly constant during the day, then slowly falls until 2 a. m., becoming a minimum at from 2 a. m. until 6 a. m.

The weight of water condensed in the worm being known and the temperature of the water of condensation, and also the weight of the condensing water and the temperature of the injection and discharge, the degree of superheating of the steam, if it is superheated, or the amount of water entrained with it, may be computed.

All the steam that was formed in the boiler and was not condensed in the worm was allowed to escape into the atmosphere through the safety valve. As the steam which flowed to the worm was drawn from the steam drum within a few inches of the safety valve, there is no reason to suppose that it was not of the same quality as the steam which

flowed through the valve. It is on the correctness of this assumption that the exactness of this method rests.

The apparatus for condensing the steam may be as small as convenience requires, and will give accurately the quality of the steam.

The total weight of steam evaporated is given by the measurement of the feed water before being pumped into the boiler.

There was a high grade thermometer in a mercury cup in the steam drum. This thermometer did not indicate as high a temperature as that due to the temperature of the steam.

Notwithstanding that the thermometer did not record the exact temperature of the steam, its variations served to show that the steam was *not super-heated.*

The temperature of the gas leaving the boiler was tested by a thermometer in a sand bath in the flue marked T in Fig. 6. Fig. 10 shows a section of the flue at the point when the thermometer was inserted, and the amount of contraction from the original size of the flue.

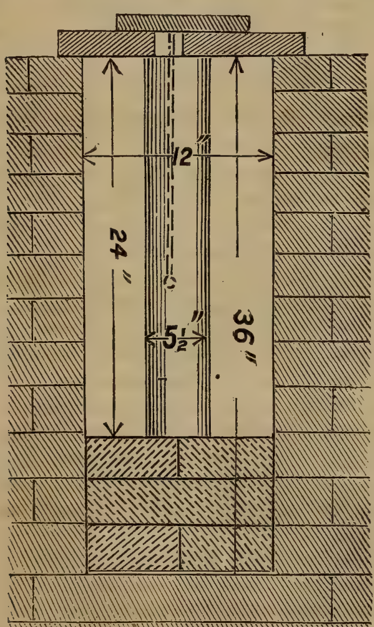


Fig. 10.

The sand bath was a piece of 5½″ iron pipe, plugged at the bottom and filled with sand. The thermometer was lowered into the pot through a hole in the tile covering the flue, which was closed with a block of wood except when the thermometer was being examined.

The temperature of the gas in the main flue was occasionally taken with the same thermometer, without the sand, at the point marked X in Fig. 6. This temperature was always considerably less than that of the connecting flue. It is believed that this difference was due to the cold air which leaked into the flue through the boiler No. 4, in Fig. 6, and mixed with the hot gas from the boiler being tested. It was believed during the experiment that all connection between boiler No. 4 and the main flue had been closed by a brick wall temporarily erected across the flue at y, Fig. 6. It was found, however, after the experiment this brick wall had partly fallen down, exposing an opening of at least one-half a square foot.

The furnace and ash-pit doors of boiler No. 4 were kept closed during the experiment, and as these doors were well fitted it is believed that no appreciable amount of air leaked in through them, but that all the air leaked through *the false front and openings in the brick-work.*

The connection between the other boilers, Nos. 1 and 2, was closed by luting the dampers provided with *fire clay.* The tightness of this joint was tested during the experiment by making a small fire of shavings in the furnaces of these boilers and watching the course of the smoke, which all returned into the fire-room through the furnace door and through the *openings in the iron front.*

The pressure of the gas in the chimney was measured by a Siphon gauge, the leg entering the chimney being a ¼″ iron pipe, continuing through the brick work to the center of the flue, the end being turned *up.* There was also a similar gauge with the end bent *down.* It was expected that the velocity of the air in the flue could have been determined by the difference of height of the column of water in these two gauges. The gauge connecting with the tube *bent down* would have measured the difference of weight of the column of air within and without the chimney, while the gauge connecting with the tube bent up would have indicated a pressure less than this weight by the weight of a column of hot

gas of sufficient to give the experimental velocity to the gas in the chimney. It was found, however, that this difference of height, although perceptible, was too small to be measured by the gauge.

This difference being the height of a column of water equal in weight to a column of hot gas through which a body falling would acquire the velocity of the gas in the chimney, may be determined as follows :

Velocity of gas in chimney from experiment in feet per second............	11.25
Weight of a cubic foot of gas at 230°...	.05988
Weight of a cubic foot of water at 60°..	62.4
Height due to a velocity of 11.25 feet...	1.9625
Weight of a column of gas 1.9625 feet high...............................	·1177
Height of a column of water of same weight......	.0226″
Measured height of syphon gauge with end bent up	.161
∴ Measured height of syphon gauge with end bent down (161 + .0226) =	.1836

A very striking example of the experimental fact that a gauge connected with a tube, having an orifice directed against the current of gas, will not indicate a less pressure than that in the reservoir from which the pressure flows, is cited by chief engineer Isherwood, U.S.N.

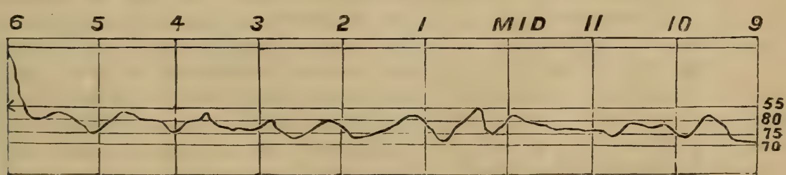
In some experiments being made to determine the necessary size of orifice for a safety-valve on a boiler, in one case a 2″ pipe 4′ long was tapped into a steam drum, both ends being open. A steam gauge was connected with a long ½″ pipe which could be run down through the 2″ pipe until the end was well inside of the steam drum.

While steam was raised in the boiler and rushing out into the atmosphere through the 2″ pipe, the gauge pipe was gradually withdrawn, and the reading of the connecting gauge noted for every position from the time when the end was on the steam drum until the time when it was several inches beyond the end of the escape pipe.

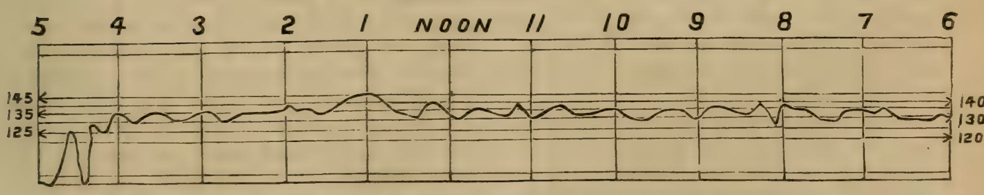
The gauge marked the nearly same pressure—nearly the pressure of the steam in the boiler—40 lbs. in every position. The copies of the logs of the two experiments following will explain themselves. The figures in the column headed "height of water in tank," indicate the readings of the gauge, and the amount of water fed in will be found by subtracting the reading of the gauge at the beginning of the interval from the reading at the end.

The following are diagrams from Edson's Recording Time Gauge, which worked well during the whole experiment, the vertical figure marking the pressures and the horizontal the hours :

1st Experiment.



2d Experiment.



Abstract of Howard Boiler, December 17th and 18th, 1874.

Total Quantities.

	1st.	2d.	Mean.
Duration of experiment hrs..	10.5	11	21.5
Lbs. of coal fed into furnace	—	—	5100
Lbs. of coal and ashes withdrawn..................	—	—	1158
Lbs. of combustible consumed	—	—	3942
Lbs. of water fed into boiler	17338	21015	37403
Lbs. of water entrained with steam..................	452	3100	3552
Lbs. of water evaporated....	16886	17915	34801
Lbs. of water condensed in worm..................	3483	5418	—
Number of minutes worm was in use...............	485	530	—

Pressure.			
Steam in boiler	76.5	138.3	—
Siphon gauge in chimney	.155	.145	.150
Barometer			
Temperature.			
Feed	35°	36°	35½
Atmosphere	35°	45°	40
Steam (by thermometer in drum)	314°	346.8	—
Gas leaving boiler	332°	324°.2	—
Gas entering chimney	—	234°	—
Water from worm	90°.7	103°.8	—
Injection	37°.5	36°	—
Discharge	59°.5	64°.82	—
Mean Quantities.			
Lbs. of combustible per hour	—	—	183.5
Lbs. of combustible per sq. foot of grate	—	—	6.8
Lbs. of combustible per sq. ft. of heating surface	—	—	0.308
Apparent evaporation per lb. of combustible	9.024	9.915	9.469
Weight of water entrained with steam per lb. of combustible	.225	1.547	—
Effective evaporation per lb. of combustible	8.798	8.368	8.543
Effective evaporation per lb. of combustible from 212°	10.75	10.28	10.53
Per centage of total absorption (useful)	.742	.709	.726
Per centage of water entrained with steam	2.6	15.5	—

DISCUSSION OF RESULTS.

From an inspection of the cuts, together with the description, it will be seen that this boiler belongs to the water tubular type, *i. e.* to that class of boiler having the water within the tubes and the products of combustion on the outside. This class of boiler has given the highest recorded economical performance of any boiler in use, being in one case as high as 90 per cent. of the total heat contained in the coal, given with a rate combustion of 6½ lbs. of combustible to one square foot of grate per hour, and with a proportion of grate surface to heating surface of 32½ to 1, both being nearly the same as during this experiment.*

It has been found experimentally that the efficiency of combustion, *i. e.* the proportion of the total heat in the fuel which is developed by its combustion does not sensibly vary within the limits of practice of steam boilers either from a variation of the rate of combustion or of the thickness of the bed of fuel on the grate.

*"It is a matter of popular belief that, owing to insufficient air admission, carbonic oxyde is formed in the furnaces of steam boilers, in which case a loss of heat would be sustained equal to that which would be developed by its further oxydation to carbonic acid." Whether such is the fact or not can only be determined by a chemical analysis of the product of combustion. Many such analyses have been made with widely varying thickness of bed of combustible and greatly different rates of combustion, but they all agree in indicating that the proportion of carbonic oxyde is very small, not exceeding about six per cent. in the worst cases, and that it is not sensibly affected by the thickness of the bed of fuel, at least not within the limits of practice. Also that the air admitted through the grate bars is about double that which is chemically necessary for perfect combustion, the free oxygen composing about 10 per cent. of the products of combustion. These analyses also show that the combustion more nearly approaches perfection in the higher than in the lower rates. In the same furnace the higher rate is attended with a less proportion of carbonic oxyde, of free oxygen, of combustible gases in the products of combustion, and with a higher furnace temperature than in the lower rate. The higher economic rates obtained in steam boilers with the lower rates of combustion must be ascribed, not to the development of more heat from the more complete oxydation of the combustible, but to the absorption of more heat from the water heating surfaces due to the less quantity of heat thrown upon them in a given time; the proportion of heating to grate surface, habitually given, not being sufficient to reduce, even with the lowest rate of combustion practicable, the temperature of the products of combustion to that of the water heated. With the heating surface increased in the same ratio as the rate of combustion, and arranged in such a manner as to have equal heat absorbing efficiency, the higher rates would probably be attended by an increased economic evaporation, though not to any considerable degree.†

* Report of Board on Horizontal and Tubular Boilers, Phila., 1868.

* Experimental Researches in Steam Engineering. B. F. Isherwood.

† Ex. Res. in Steam Engineering, Vol. II. p. LXIII.

THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE.

By Capt. J. ERICSSON.

From "Nature."

The observations relating to the temperature of the polar regions, referred to in the article (vol. xii., p. 517), at first led to the supposition that the rays projected from the north pole of the sun transmit a perceptibly greater energy to the actinometers than the rays from the opposite pole. Subsequent observations having positively established the fact that the polar and equatorial zones transmit equal intensities, it became evident that some other cause than difference of temperature within the polar regions influenced the actinometers. The only valid reason that could be assigned in explanation of the anomaly being the considerable angle subtended, and the consequent difference of zenith distance of the opposite poles of the sun, my table of maximum solar intensity for given zenith distances (prepared from data collected during a series of years) was consulted, in order to ascertain the influence of zenith distance. The observations indicating a higher temperature at the north pole, it should be mentioned, had been made while the sun's zenith distance ranged beeween 32° and 33° at noon. Now the table referred to shows that there is a difference of radiant intensity of $63°.63 - 63°.40 = 0°.23$ F. between the stated zenith distances. The mean angle subtended by the sun being fully thirty-two minutes, it will thus be seen that owing to the absorptive power of the terrestrial atmosphere, the radiant intensities transmitted from the opposite poles of the luminary differ considerably. The magnitude of this difference, adequate to explain the discrepancy under consideration, need not excite surprise if we consider that thirty-two minutes of zenith distance involves an additional depth of more than half a mile of atmosphere to be penetrated by the rays projected towards the actinometer from the *south* pole of the sun. The foregoing facts show the necessity of taking the difference of zenith distance between the opposite poles into account in making exact observations of the sun's polar temperature, especially at the lower altitudes where the secant of the zenith distance increases rapidly.

Regarding the calorific energy of the radiation emanating from the border of the sun, I deem it proper to present the following brief statement. Several observations during the early part of the investigation pointed to the fact that increased energy is transmitted to the actinometers by radiation from the sun's border. Again, considerable irregularity was observed in the progressive diminution of the force of radiation towards the circumference of the solar disc. It was shown in the preceding article (vol. xii. p. 520) that the radiation from the border zone, 1′ 42″ wide, occupying one-fifth of the area of the solar disc, transmits 0.638 of the intensity transmitted from an equal area at the centre of the disc. Of course it will be supposed that the rate of the diminution of intensity within the zone thus ascertained is much greater near the border of the photosphere than at the middle of the zone. Such, however, is by no means the case, notwithstanding the assumption of physicists that the heat transmitted by radiation from the border is very feeble. In order to test the truth of the indications referred to, showing considerable radiant energy at the border of the photosphere, a very careful investigation was made, Sept. 9, 1875, by means of screens excluding the ray from the solar disc, as shown in Figs. 12 and 13. The diameter of the screen represented in Fig. 12 being 154.06 millimetres, covered nine-tenths of the area of the disc; while the screen shown in Fig. 13, being 145.25 millimetres, covering four-fifths of the disc. It will be well to mention that the dimensions of the screens referred to correspond with the angle subtended by the sun when the earth is in aphelion. Ac-

cordingly the distance between actinometers and the screens was adjusted previous to the observation, viz., shortened, in order to compensate for the increase of the angle subtended by the sun. Agreeable to the stated dimensions of the screens, it will be found that the zone represented in Fig. 13 is 1′ 42″, while the zone in Fig. 12 is 49″.6. The mean width of the latter is consequently situated only 24″.3 from the border of the photosphere.

The following table shows the intensities transmitted to the actinometers from the zones represented in Figs. 12 and 13:

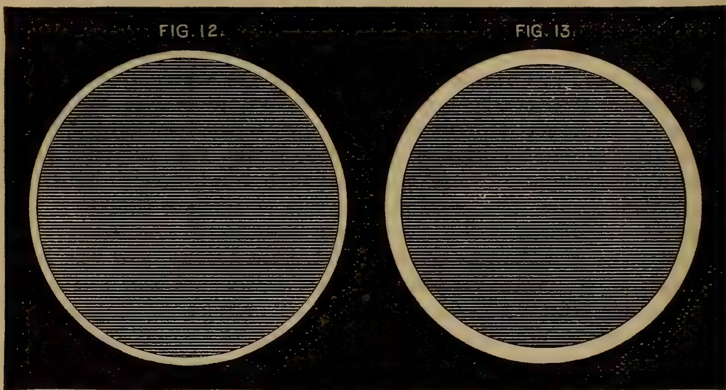
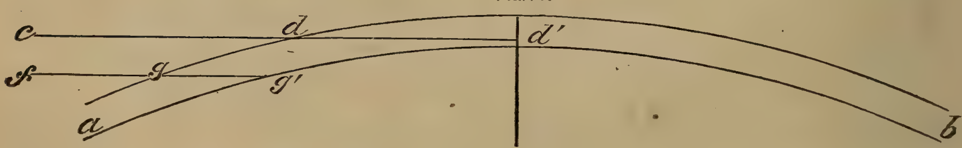


FIG. 12. FIG. 13.

Time.	Zone, Fig. 13. Cent.	Zone, Fig. 12. Cent.	Rate of difference.
4′	2°.011	1°.333	$\frac{1.333}{2.011}=0.662$
5′	2°.248	1°.471	$\frac{1.471}{2.248}=0.654$
6′	2°.425	1°.538	$\frac{1.583}{2.425}=0.652$
7′	2°.485	1°.666	$\frac{1.666}{2.485}=0.670$
			Mean=0.660

The rate of difference inserted in the last column, it will be noticed, is not quite so consistent as in the table contained in the previous article recording the observations made Aug. 25. The discrepancy is, however, not material, the difference between the lowest and the mean rate being 0.008. It will be seen on inspecting the registered intensities, that the border zone represented in Fig. 12, whose area is only one-half of the area of the zone in Fig. 13, transmits 0.660 of the intensity of the latter.

IG. 14.



This at first sight indicates an extremely disproportionate transmission of heat from the narrow border zone; but it should be considered that the inflected radiation imparts relatively more heat to the actinometer exposed to the radiation from the narrow zone than from the wide zone. It will be readily understood that since the inflection of the calorific rays is 14″.7 (see preceding article), the first-mentioned actinometer receives radiant heat from 14′.7+49′.6=64″.3; while the actinometer exposed to the radiation from the wide zone receives heat from 1′ 42″+ 14″.7 = 116″.7. Consequently, the radiant heat emanating from the narrow zone will be $\frac{64''.3}{116''.7}=0.551$ of that transmitted from the wide zone, hence somewhat more

than one-half. Our investigation therefore proves that the radiant heat transmitted from the narrow border zone represented in Fig. 12 is 0.660 — 0.551 = 0.109 more intense than that transmitted from the zone represented in Fig. 13, although the mean distance of the latter is twice as far from the border of the photosphere as the mean distance of the former. The singular fact thus revealed can only be accounted for by supposing that internal radiation is not incompatible with the constitution of the photosphere, and by adopting Lockyer's views expressed in the Senate House of Cambridge, 1871, that "the photosphere must be a something suspended in the solar atmosphere."* Let *a b*, Fig. 14, represent a section of the "suspended" photosphere, and *d c*, *g f*, rays projected towards the earth. Agreeable to the conditions mentioned, and in view of the fact that the force of radiation from incandescent gases presenting equal areas, varies nearly as their depth, we are warranted in concluding that since the depth $d\ d'$ is greater than $g\ g'$, the radiant heat transmitted from the photosphere by the ray *d c* will be greater than that transmitted by the ray *g f*. It shoulld be observed that the energy transmitted towards the earth by *d c* suffers a greater diminution than the energy transmitted by *g f* in consequence of the greater depth of the solar atmosphere penetrated. Hence the augmented energy established by our investigation, does not show the full amount of the increase of radiant heat transmitted from the border of the sun.

THE EIGHTY-ONE TON GUN.

From "Engineering."

During the last and present months further experiments have been made at the proof butts of Woolwich Arsenal with the 81-ton gun, in the view of testing its capacity with its present calibre of 14½ in., before the bore is enlarged.

THE 81-TON GUN: PARTICULARS OF EXPERIMENTAL FIRING.

Number of Round.	Weight of Projectile.	Weight of Charge.	Size of Powder Grains.	Density of Powder.	Muzzle Velocity.	Pressure per Square Inch of Gun.	Foot-tons of Energy per Inch of Shot's Circumference.	Total Energy in Foot-tons.	Foot-tons per Pound of Powder.
	lb.	lb.	in. cubes		ft.	tons.			
1	1260	220	1.5	1.76	1525	25.8	445.94	20,313	92.33
2	1260	220	1.7	1.76	1420	20.6	386.66	17,612	80.05
3	1260	230	1.7	1.76	1454	20.2	405.39	18,465	80.28
4	1260	240	1.7	1.76	1470	21.0	414.37	18,874	78.64
5	1260	220	1.5	1.78	1505	24.1 to 26.3	434.33	19,784	89.93
6	1260	220	1.7	1.78	1502	23.0	432.59	19,705	89.57
7	1260	220	2	1.78	1481	21.7	420.60	19,157	87.08
8	1260	230	1.7	1.78	1543	24.9	456.54	20,796	90.41
9	1260	230	2	1.78	1498	23.4	430.30	19,598	85.22
10	1260	240	2	1.78	1513	23.0	438.95	19,995	83.31
11	1450	220	1.5	..	1440	28.0	437.57	20,842	94.74
12	1450	220	1.7	..	1414	25.0	442.22	20,097	91.35
13	1450	220	2	..	1366	24.4	411.75	18,756	85.25
14	1260	250	2	..	1522	24.8	444.78	20,259	81 04

In the first series of trials the powder charges varied from 170 lb. to 240 lb., and the weight of projectiles from 1258 lb. to 1260 lb. A maximum muzzle velocity of 1550 ft. was then recorded, with a total striking energy of 20,984 foot-tons, and a pressure on the powder chamber of 29.6 tons per inch, a strain far beyond the assigned limits. The table above summarises the practice made with the gun since the trials above made.

From these figures it will be seen that the ranges of powder charges varied from 220 lb. to 250 lb., and the weight of projectiles from 1260 lb. to 1450 lb., while the pressures recorded increased from 20.2 tons to 28 tons per square inch, the latter being given by the smallest size of powder employed, namely, 1 in. cubes. Of the series, round No. 8 shows the most favorable result, as with a 230 lb. charge of medium-sized powder, and a pressure of 24.9 tons, a muzzle velocity of 1543 ft. was obtained, and a total energy of 20,796 foot-tons, equivalent to a duty per pound of powder burnt of 90.41 tons. Comparatively small increase in striking energy was obtained by using the heavier projectile, while the pressure on the gun increased considerably. The maximum strains were produced by the smallest cubes of powder, and the largest size, whilst not throwing so much work on the gun, put less into the projectile. The powder in 1.7 in. cubes, therefore, appears in all respects best suited for the work. The advantage lay also with the use of the shot of 1260 lb., instead of the heavier projectiles, of which three rounds were fired.

The total amount of energy per pound of powder charge in the 81-ton gun, as compared with that of the lighter calibres is of interest. Thus if we take the Woolwich and Krupp 10 in. guns, which Mr. Longdon was the other day contrasting with each other, greatly to the disadvantage of the former, we find that the figures are as follows :

(*See Table on following column.*)

	Powder Charge	Total Energy.	Foot-tons per Pound of Powder.
	lb.	foot-tons.	
81-ton gun.........	230	20,796	90.41
10-in. Woolwich gun	70	5,160	73.70
9-in. Krupp.........	84	6,610	66.70
10-in. Krupp........	100	6,270	62.70

From the performance of the Krupp guns it would appear as though the work done by the powder diminished with increase in calibre, though of course so partial a comparison forbids any actual conclusion.

The 81-ton gun is, we believe, to be immediately enlarged in calibre from 14½ in. to 16 in., when a fresh and still more interesting series of trials will be commenced. So far as experience has gone, we may fairly congratulate ourselves on possessing the largest useful piece of ordnance in the world. We say useful, because no trials have been ventured upon with the monster gun made some years since by Herr Krupp. We believe, however, that some pieces of ordnance as large, if not larger, than our 81-ton gun, are now in progress in Essen, and when completed they will no doubt be as perfect representatives of steel ordnance as the 81-ton gun is of the Woolwich system. We shall look forward with interest to the trials of these large Krupp guns, for not only will they test the reliability of steel ordnance to the utmost, but ample experience of the efficiency in the largest calibres, of the Broadwell system of breechloading as employed by Krupp will also be ascertained.

THERE are eight completed Bessemer steel establishments in the United States, and every one of them, says the *Bulletin Iron and Steel Association*, is running to its full capacity, and is full of orders. Two of these are at Chicago, one at Joliet, and one at Newburg, near Cleveland. The new Edgar Thomson Bessemer works near Pittsburg, a magnificent plant, will soon be in operation, and the Bessemer plant of the Lackawanna Iron and Coal Company at Scranton will also be completed soon. At St. Louis the Vulcan Ironworks are at work on a Bessemer plant, to be ready this year, making the eleventh in the country. It will be observed that, if we include Pittsburg, the west will have six of the eleven.

THE ARCH QUESTION AGAIN.

By CHAS. A. SMITH, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

In an article published in this Magazine, p. 514, vol. 13, Dec., 1875, Mr. Wm. Cain, A.M., C. E., makes some statements calculated to convey wrong impressions, as follows:

He says, "As to the usual statement that a line of pressures cannot pass outside of the middle third of the arch ring without the arch tumbling (a fallacy of Rankine and other authors) we have only to remark that experiment undoubtedly and finally disproves it." The above quotation only leads me to infer that Mr. Cain is ignorant of the statements made by Rankine, whatever he may have taken from other authors. Rankine says expressly (vide "Civil Engineering," p. 220) "The properties which the line of resistance and line of pressures must have in order that the conditions of stability may be fulfilled, are the following:

"*To insure* stability of position, *the line of resistance must not deviate from the centre of figure of any joint more than a certain fraction of the diameter of the joint measured in the direction of the deviation.*"

I do not suppose Mr. Cain is inclined to dispute the above condition, and the only question left is the amount of the ratio of the deviation admissible. Rankine calls the ratio of deviation "q," and says on p. 397: "The following are average values of 'q' deduced from the dimensions of actual retaining walls. According to the practice of British Engineers 'q' = 0.375 nearly."

That is, the line of resistance must not pierce any bed joint nearer the edge than one-eighth of the diameter of the joint. This is a limit of deviation that even Mr. Cain would hardly wish to pass.

Rankine, however, says in regard to flying buttresses (p. 396), and arches (p. 416): "It is advisable to limit 'q' so that there shall be no tension at any part of the joint which for rectangular joints gives 'q' = $\frac{1}{6}$." This is the value Mr. Cain thinks so fallacious, but of which Rankine says (p. 417): "It is true that arches have stood, and still stand, in which the centres of resistance of the joints fall beyond the middle third of the depth of the arch ring, but the stability of such arches is either now precarious or must have been precarious while the mortar was fresh."

In order to fully impress Mr. Cain with the importance of this last quotation, it will be necessary to remind him that engineers usually require for all classes of work a certain margin or factor of safety, and that limiting the curve of pressures to the middle third of the arch ring is identical with employing a factor of safety of 3 in the overturning moment, which most engineers think is small enough for a structure involving the safety of a railway train. A blockwork structure will not open the joints, until the pressure line passes through the edge of the joint, but the edge through which the pressure passes will usually "spawl off" and cause failure, from the material giving way to the compressive stress (which is theoretically infinite, when the line of pressure touches the edge).

The work of Rankine, as a teacher, is to place before the engineer the various cases which may occur, and the working engineer alone can decide which cases his problems come under. The question of load on rafters has been taken up too many times for me to enter upon it here, and I will let it pass with the remark that there is more in Rankine's Civil Engineering than some men find in it.

Mr. Cain casts a slur at the profession when he says "The engineer, strange to say, is not so fond of experimenting, but prefers to *assume* and compute the deduction." I must as a member of the profession say that most engineers of my acquaintance prefer experiments, and what is far better than experiments, viz., successful practice, to any computed "deductions," and certainly no one kind of structure has so many examples of successful practice as the "blockwork arch." Telford erected over one thousand stone arches during his life, and any one needing a precedent can cer-

tainly find one for any kind of "block-work arch" in which he need be troubled with only a very limited amount of calculation. Every completed structure is in itself an experiment and certainly the first question asked by the true engineer for every problem new to him is not "how can I compute this case?" but "how has it been solved?" and after that has been answered "how can the former solutions be improved, and what better one can be given?"

LAND DRAINAGE.

From "Engineering."

For some time past the unusual rainfall has resulted in floods more or less severe, which have been the subject of much general anxiety and local damage. On the Continent as well as in this country, the rainfall during the present year has been peculiarly disastrous; it is true that, periodically, we are liable to an excess of rainfall, and consequently partial inundation of the low-lying districts of the country. But recently the floods which have been experienced have had extraordinary results in the destruction of life and property, and this circumstance suggests many points of interest in regard to land drainage, water supply, the pollution of rivers, and cognate subjects. Although the matter is one of national importance, its details involve to a large extent questions of local inquiry, and it is to these we shall briefly draw attention.

It must be expected that an extraordinary rainfall, in any country, must give rise to floods in low-lying districts, if we only consider the natural obstructions that exist in the course of most rivers that run into the German Ocean. Such natural obstructions consist in bends of the river beds, upheavals of the bottom, weeds, stumps of trees, &c. But beside these, are artificial obstructions caused by the introduction of refuse of all kinds, but especially in mining and agricultural districts. In our mining districts the quantity of refuse thrown from metaliferous and coal mines is enormous, and such causes have been already noticed in our columns when we criticised the reports of the Royal Commission on the Pollution of Rivers. In regard to agricultural causes it is simply necessary to state that whenever a flood occurs, and this generally happens in autumn or spring, when the land has been newly ploughed, a very large proportiou of the surface soil is washed into the adjacent stream, where it gradually settles, lessening the depth, and consequently flooding land lower down on the banks of the river. Last week the nothern piers of Vauxhall Bridge were thus coated with a covering of upwards of a foot deep of soil brought down from the upper portion of the Thames during one tide, and this minor instance is but a slight indication of the enormous deposit cast into our rivers through the washing of the surface soil from adjacent fields.

During the present week we find that at Hampton, Kingston, Richmond, and adjacent places, the Thames has been swollen to an extent unknown for years past. At the intakes of the Metropolitan Water Companies the water was consequently very turbid; in fact it was opaque if viewed to the depth of one inch, according to our own observation. The water, before being drawn into the Thames Companies' reservoirs, was loaded consequently with soil, manure, sewage, and every imaginable abomination that newly ploughed and manured fields, and towns could supply. The extent of pollution caused by the fields may perhaps be little known by some of our readers, but one instance may suffice to show how floods may cause such pollution. Three years ago, for example, a farmer manured heavily a ten-acre field not far from Leeds, on the banks of the Aire. A heavy flood came, and the whole of the manure was swept off on to an adjacent field, which produced well in the following season, while the field originally manured was nearly barren. Now, precisely the same circumstance has been going on, say, during the last few weeks on the banks of all our rivers running eastwards. Most of these, and

their tributaries, are sources of water supply. What a sarcasm does not this fact convey on the action of local authorities, and the advance of engineering science!

The question arises as to whether such results of flood may either be prevented or alleviated, and the latter we consider might be largely accomplished. In countries where floods are perennially expected, provisions are made to obviate ordinary consequences, as in Holland, Egypt, India, and some portions of the United States. Dams and other means are adopted, and even in our own country, the Lincolnshire fens, parts of Bedford and Cambridgeshire, &c, are similarly protected. But in our Midland Counties things are left to their fate. For the last thirty years we have noticed in traveling northwards from London, that about 15 miles from town floods have constantly occurred during autumn and winter, and yet scarcely any attempt of a systematic kind has been made to cure so serious an evil. The farmer has left the flood to wash his seed and manure into the river, and the town authority up to the Registrar-General, has rejoiced to find that the flood has cleansed sewers and reduced the rate of mortality. The first, like the Turk, has submitted to fate with resignation, while the other has rejoiced on the principle that partial evil generally results in general good. And so we have been content to suffer evils rather than seek a remedy,

A very little consideration would show that if land were properly drained, the danger of floods would be materially lessened in the majority of cases. A badly sewered town must constantly be flooded, of which some hundreds of instances have been reported during the last fortnight. But a place like the metropolis, with adequate sewerage, cannot be flooded. Just so in respect to land. If a ready means be provided for the removal of surface water, not only is the chance of flood diminished, but the surface soil and the newly laid manure and seed are kept in their place, Thus several evils are in whole or in part remedied by efficient drainage and improvements, and to this we must therefore in future look for means to lessen the evil results of excessive rainfall.

But a more refined point of science is involved in the question of rainfall. It has long been established that in the same locality, at different altitudes, and at the same moment of time, more rain falls on the ground than is produced at a certain height above it ; even a high house shows a less rainfall on its roof than at the basement. This is easily explained. Each drop of rain as it falls accumulates moisture, and consequently increases in quantity. In damp, marshy, and undrained districts, the supernatant atmosphere is loaded with suspended aqueous vapor, consequently the rainfall in such districts generally exceeds that of a similar land and level when well drained. In other words, a well-drained land will, all circumstances being equal, have a less rainfall than one that is badly drained. Hence efficient drainage may from meteorological causes tend to diminish floods. Equally, a land destitute of trees has less rainfall than forest land. Hence it is actually in our power to control natural phenomena to a very large extent with respect to great rainfall and consequent floods.

Passing from scientific to practical questions there is one remedy that has been greatly neglected, and which affords a ready means of largely controlling the effects of a flood—we refer to the proper management of locks and weirs.

Most of our English rivers, above the tidal stream, have been converted into canals, and are also used to provide motive power for mills. Both of these modes of utilizing the stream involves the necessity of keeping a "head" of water. Self-interest and neglect tend in numerous cases to keep up this "head" preceding and during floods, to an unnecessary extent. When the evil has occurred the water is lowered by opening the sluice, but owing to a want of impetus or motion in the water, already at rest, the new flood sweeps over it as if it were a solid mass, and, consequently, the late opening of the sluice becomes practically useless. Numerous instances of this kind have recently come under our notice, in which the lower parts of towns have been unnecessarily flooded with a comparatively small rainfall, while, with a greater, the evil was avoided by a timely attention to the precautions we have alluded to.

Of course the erection of dams and

similar contrivances must be attended with great expense, but even this would be repaid if we calculate the immense loss of property compared with the annual charge of interest on loans necessary for such precautions. It is only a year or two back that in the metropolis itself damage was done to the extent of several thousands of pounds in a few hours that might have easily and cheaply been prevented, and it was amusing if not edifying to have noticed the enormous amount of clay used alike by the Metropolitan Board of Works on the Thames Embankments, and by the poor laundry woman on the Lambeth and Southwark banks, to protect property from the sudden flood of the Thames within even City limits. Such matters should not occur in our present state of engineering science.

We have thus briefly drawn attention to some important questions that naturally present themselves for consideration, owing to the extensive floods that have prevailed for the last fortnight. It is evident that we have abundant means within our reach to largely diminish the evil and losses which sudden and excessive rainfall has brought down. The loss of property and life which has occurred is serious enough, but when the evil that may arise to our water supply is also properly estimated, there is surely sufficient stimulus to set about some active measure throughout the country, to remedy or prevent a recurrence of such misfortunes, especially as so many other important sanitary matters are involved in the question. We are glad to find that the Local Government Board has just issued a commission to make preliminary inquiry into the drainage of the Thames Valley as far as Windsor, under the direction of Lieut.-Colonel Ponsonby Cox, of the Royal Engineers. This course has been adopted at the instance of the Improvement Commissioners for the district of Surbiton. It is intended that the inquiry shall include Acton, Chiswick, Croydon, Ealing, East Moulsey, Epsom, Eton, Ham, Hampton, Kingston, Richmond, Staines, Surpiton, Teddington, Twickenham, Wimbleton, and Windsor. We trust that the inquiry will be impartially conducted, and that it will result in proposing some general scheme in place of the patchwork attempts that have hitherto been made throughout the district.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—With a view to aid in a proper representation of American Engineering progress and practice at the Centennial Exposition, this Society, at its Annual Meeting, appointed a committee to consider the subject, and to take such action as might seem desirable.

It is proposed to urge Engineers who are or have been in charge of important, novel or interesting works; railroad, canal and other public corporations, and especially builders or manufacturers willing to make their works known, to present such specimens, models, plans, photographs and descriptions as shall give to visitors at the Exposition an adequate and correct idea of engineering progress and practice in this country, and to exhibit the same either in groups or under the general classification as may be preferred.

It is also proposed to have a Secretary in attendance during the Exposition, to give such detailed information as by an inspection of the models, plans, &c., exhibited, visitors may be led to ask for.

It is expected that arrangements will be made to have memoirs prepared, setting forth the progress and present state of the several branches of engineering in this country.

With this view the following sub-committees have been formed:

I. On Railroads and Rolling Stock.
II. On Bridges and Bridge Construction.
III. On Water Works.
IV. On River and Harbor Improvements.
V. On Canals and Inland Navigation.
VI. On Hydraulic Motors and Machines.
VII. On Foundations and Masonry.
VIII. On Parks and Landscape Gardening.
IX. On Sewerage and Sanitary Engineering.
X. On Light-Houses and Signals.
XI. On Steam Engineering.
XII. On Metallurgical Engineering.
XIII. On Surveying and Geodesy.
XIV. On Gas Engineering.
XV. On Mechanical Engineering.
XVI. On Correspondence and Circulars.
XVII. On Rooms and Representation.
XVIII. On Arrangements and Space.
XIX. On Finance.

The Committee solicits assistance of members in the matter, either in contributing specimens, models, plans, photographs and descriptions to be presented, or by inducing others to do so. As the time is short, it is desirable that preparation should begin at once.

Civil and Mechanical Engineers' Society. Session 1875–76 of this Society will commence on December 9th, when the President, Mr. W. F. Butler, A.I.C.E., will deliver an opening address. The following is the syllabus of papers for the Session:—

Dec. 23d, 1875.—"London Bridge and its Traffic." By Mr. A. T. Walmaisley, C. E.

Jan. 13th, 1876.—"Trade Unions." By Mr. Charles H. Rew.

Jan. 27th.—"The Testing and Strength of Materials." By Mr. R. M. Bancroft.

Feb. 10th,—"Permanent Way of English and Foreign Railways." By Mr. W. C. Street.

Feb. 24th.—"Aquaria and their Construction." By Mr. C. H. Driver, architect.

March 16th.—"The Hoarworthy Bridge over the River Wye." By Mr. C. W. Whitaker, C. E.

March 30th.—"Concrete Flooring." By Mr. Alexander Payne, architect.

April 13th.—"Hydraulic Machinery." By Mr. Thomas M. Gray.

April 27th.—"The Spectroscope." By Mr. B. Haughton.

May 11th.—"Railway Rolling Stock." By Messrs. P. Burrell, C. E., and H. Valpy, C. E.

May 25th.—"Steam Tram Cars." By Mr. E. Perrett, C. E.

The annual meeting will be held on June 15th. Visits to various works in progress will be made during the session.

Engineering Society, King's College, London.—A meeting was held on Friday, Oct. 15th, Mr. E. W. Anderson, vice-president, in the chair, and the minutes of the previous meeting having been read and confirmed, Mr. Crompton read a paper on "Railway Time Tables." The author began his paper by treating of railway unpunctuality as connected with and giving rise to accidents. He also looked for the cause of this unpunctuality as originating in the "time tables." He next discussed the reasons for and against the making of stations at the top of inclines; and then proceeded to consider and compare the fastest trains on each separate line running from London, making a few remarks on each. A discussion followed in which Messrs. Pollock, Kirkman, Little, Strange, and Mackworth took part. The chief object of the gentlemen who spoke seemed to be to show the error of certain statements made by the author, and the opinion given by him as to the desirability under certain circumstances of having six lines of rail where the traffic is large, formed the chief object of attack. Mr. Crompton replied, and the meeting adjourned, after a vote of thanks had been passed to Mr. Crompton, at 4.50 p. m.

Genevan Society of Arts.—On the occasion of the centenary of the Genevan Society of Arts, founded in 1776, that body proposes to offer a number of prizes in its various departments. A service which the Academy will render to horology will be the international competition in the regulation of pocket chronometers. The trials of these chronometers will take place at the Geneva Observatory, under the superintendence of M. Plantamour, the director. All chronometers intended for the competition must be forwarded to him before mid-day of February 14, 1876. All competitors not resident in Geneva should correspond with the Observatory through a resident agent, who will manage all the details. M. J. B. Grandjean, president of the Section of Horology of the class, offers his services gratuitously to makers who have no agent in Geneva. Each chronometer should be accompanied by a paper containing data to identify the chronometer, details of its construction, &c. The trial will last fifty-two days, from February 15, 1876, divided into nine periods. In a hot chamber and in an ice-house (*glaciere*), the chronometers will be tested by being placed in all possible positions. All chronometers not complying with the following conditions will be excluded from competition: 1. The mean variation from day to day ought not to exceed six-tenths of a second so long as the chronometer preserves the same position in the Hall of the Observatory. 2. The values which express the mean rates during each of the periods except that of the hot chamber and the ice-house, ought to agree with their mean in the limits of two seconds more or less. 3. The error of compensation determined by the comparison of the rates in the hot chamber and in the ice-house ought not to exceed two-tenths of a second of degree Centigrade. 4. The difference of rates between periods six and nine (both in the Observatory-hall, horizontal position, dial above), *i. e.*, before and after the proofs relative to temperature, ought not to be above one second in twenty-four hours. The value of the results obtained in the trials which concern the two former conditions will have an importance double that which will be given to the two latter. No competitor can receive two prizes. A sum of 3,000 francs at least will be devoted for the purpose of awarding gold medals, or an equivalent value, to competitors who have been judged worthy. A number of medals in silver and bronze will also be awarded. Those who wish for further details concerning this and other competitions should apply to the secretary of the academy.

IRON AND STEEL NOTES.

The Ores of Iron Considered in Their Geological Relations.—After some very interesting introductory remarks, Mr. Smyth said, omitting the discussion of certain silicates, rarely employed for smelting, and of iron pyrites, the ores to which he woudd direct the attention of his audience were simply the oxydes as met with by themselves, or combined with water or carbonic acid, and which formed the great bulk of the material employed in iron making. First in order of the ores thus limited was magnetite. This mineral, with 72.41 per cent. when pure, was the fine rich ore which had been worked with great success for centuries in several of the Scandinavian mines. In Italy fine examples of magnetite were also found, as well as in several widely-separated places in North America. Magnetite only occurred in a few localities in Great Britain, amongst which the vicinity of Penryn, in Cornwall, and Hey Tor, near Bovey, in Devon, were mentioned. In two localities in North Wales a minutely crystalline form of this mineral occurred, but it had never been opened out with perseverance, and was said to be in some places pyritons. The next species noticed by the lecturer was hematite. This ore so little recognized thirty years

ago, was now too well known to require to be enlarged on. Mr. Smyth, however, referred to its strange discovery in Furness, near Whitehaven, its having been worked for years in the Mendip Hills, and its occurrence in abundance in Spain and North America, the deposits in both these latter cases being of a bedded character. He next described the curious ores named bauxite and wochenite, in which alumina takes the place of the sesquioxyde of iron, turgite, gothide, limonite, chalybite, the last named often mixed with other ores on a larger scale. The most important deposit of this last-named ore was contained in the range of veins occupying a length of some thirty miles in Somerset and North Devon from the Raleigh's Cross westward to near Ilfracombe. There was also the fine lode of Perran, sometimes 100 feet across, if taken horizontally from wall to wall, where workings commenced in brown ore had opened downwards, at depths of from 30 to 120 feet, into large masses of chalybite. The varieties of ironstone next referred to, in which the carbonate was mingled with a very variable amount of clay, of lime carbonate, or of carbonaceous matter, were, the lecturer said, thoroughly well known from their wide diffusion over the country and their commercial importance. They were, in fact, objects of more interest to the smelter than to the mineralogist. Certain of these, as the celebrated Cleveland ore, dated their employment from a very few years ago; others, like the dark pisolitic masses of the palæozoic schists of Anglesey and North Wales had hitherto met but little attention. Proceeding next to show the relationship between the oxydes, the lecturer exhibited a specimen of ore having the appearance of chalybite or spathic ore, being covered with the large rhombohedral crystals characteristic of that species, but which the presence of the brown streak, and of water, and the percentage of iron proved to have been turned into brown ore. A fragment from the lodes of the Deerpark in Exmoor, next shown, had also lost its carbonic acid, had acquired oxygen and water, and actually become a different substance. The first stage of the change might be observed in heaps exposed on the shaft tips even for a few months; a brown tint, heightening with time, took the place of the yellowish gray, and showed that a chemical action attacked the exterior, and proceeded towards the interior. It had been argued that the change commenced with the formation of the more hydrated species, and passed through successive stages to those with the least amount of water; but on that point evidence was as yet defective. The brown ores were undoubtedly (for the process might be watched in the workings) formed by another series of changes from pyrites through the sulphate of iron. The crystals of brown ore, in the form of pyrites, were among the best known pseudomorphs, and there were localities which invited the inference that this action had taken place on an important scale. To proceed a step further, it had long since been argued that red ore was a pseudomorph of brown ore, and the most notable of the proofs adduced was that from a specimen from Rostermel, which ultimately, however, turned out to have been manipulated by a roguish dealer. At the same time it had been shown by Morgans that a good deal of red ore had been found in the Raleigh's Cross vein, which might probably have passed through the intermediate hydrated stage. Mr. Smyth said he would not, in the present brief sketch, venture upon the vexed question of the original deposition of the great northern masses of hæmatite, although strong arguments for their having been chalybite might be adduced from the occurrence of limestone fossils turned into red ore. In conclusion, he brought under notice another change of condition among the oxydes of iron. It was a significant fact that magnetite was characteristic of the older formations—of those bodies of rock which had during the longest period of time been exposed to the influences which bring about metamorphosis and change of substance. In the Perran lode small portions of magnetite had been formed among the brown ores near the surface. In some of the Cornish copper lodes specimens of magnetic ore had occurred which looked very much as if they had been carbonates, and amongst the beautiful red ores of Siegen small grains of magnetite appeared to testify to a partial change, while there appeared to be sufficient grounds for believing that, in many cases at least, this last change in the degree of oxydation might be produced by the ordinary action of natural causes.

RAILWAY NOTES.

M. Herzog, engineer-in-chief of the Hungarian railways, after a series of experiments on the magnetization of rails, gives the following as his conclusions:—(1) The rails, which are taken up and replaced after several years of service, do not by any means deserve to be called powerful magnets, since a steel rail about 40 square centimetres, 6.16 square inches, in cross section, manifests immediately upon its removal a magnetic force scarcely equal to that of a saturated steel plate half a square centimetre in section. It is to be observed, however, that steel rails possess a much higher magnetic power than rails of ordinary iron. (2) Rails in place are also magnetic, and this whether the fish-plates are removed or not, provided there is between them the space usually allowed for expansion in all well-constructed lines. (3) Rails removed from the roadbed and piled up show traces of magnetism even after many months. This persistence of the effect is more pronounced in Bessemer rails than in those of ordinary iron. (4) A rail thrown out of use in consequence of fracture shows on the two surfaces of separation opposite polarities. This is precisely the same fact which is observed when a magnetized bar is fractured; there are as many magnets as there are pieces. (5) Entirely new rails, which have never been in actual service, acquire feeble magnetic properties when they are arranged in piles and placed parallel to the magnetic meridian. This remark applies more

particularly to steel rails, which, under the influence of a few blows with the hammer, are converted into permanent magnets. This last observation leads M. Herzog to the conclusion that all these phenomena are attributable to terrestrial magnetism, and are only a confirmation of the following theoretical principles: (*a*) A bar of iron placed in the direction of the dipping needle, becomes a magnet under the influence of terrestrial magnetism. The same is true for any bar of iron placed in the magnetic meridian; its magnetic intensity diminishes in proportion as the angle between the two increases. This fact is very noticeable with rails laid on a curve; the more they vary from a north and south direction, the less intense is the magnetism at their ends. (*b*) A bar of iron exposed for a long time to the influence of terrestrial magnetism becomes a permanent magnet. (*c*) For steel rails, the effect is more prompt, and more intense than for iron ones. Under the action of the hammer, they become permenent magnets. This latter effect is produced daily upon rails in use, since they are submitted at the same time to the combined influence of terrestrial magnetism, and the jars produced by the passage of trains.—*Engineer.*

The speed of trains in Germany is illustrated by a report of the railroad bureau of the empire for the month of December last. It states that the greatest speed per hour, including stops at intermediate stations, was, for express and fast trains, 34 miles on the Berlin, Potsdam and Madgeburg road; for ordinary passenger trains, 25 miles per hour on the Maerchen and Posen road. The slowest speed was for express and fast trains 21 miles per hour on the East Prussia Southern Road; for ordinary passenger trains, 16 miles per hour on the Ermsthal and the Cromberg roads of Wurtemburg. The average speeds per hour were, for express and fast trains, 28 miles; for ordinary passenger trains, 21 miles. This is for the whole empire, except Bavaria.

The Winchell Car Ventilator.—This apparatus, which has been recently tested on a car of the Cincinnati, Hamilton and Indianapolis Road, is thus described:—"The apparatus consists of an air-chamber attached to the roof, and extending the entire length of the car. Each end is supplied with a hood protected by very fine wire gauze screens, through which the air and nothing else is admitted to the chamber. Each drum is furnished with a cut-off, operated by a lever within the car, by means of which the supply of air may be regulated to a nicety. A number of registers in the bottom of the chamber admit the air to the car. When the train is in motion, the cut-off in the forward end of the car is opened, and the air enters, passes down through the registers into the car, and, having served its purpose, makes its exit through the rear hood, or, if the windows are open, through them In connection with this air chamber, and for summer use only, are deflectors on the outside of each window, which, acting as an exhaust, not only draw out the impure air from the car, but prevent the admission of smoke, dust, cinders and rain through the open window. These deflectors, being made of glass, do not in the least impede the view from the windows. They are operated all at once, by means of an iron rod running along the side of the car."

The Collision at Kildwick.—In consequence of a statement made by one of the principal officers of the Midland Railway Company, with reference to the collision at Kildwick, to the effect that the engine-driver of the mail train would have been able, with the means at his disposal, if traveling at the rate of 50 miles per hour, to stop his train in 400 yards, certain brake experiments were made in the presence of Captain Tyler on the Derby, Castle Donnington and Trent line, recently. There were four trials. In the first of these experiments, tender brake and one guard's van brake at rear of train were applied, sand used, and engine reversed and steam against it, with the Le Chatelier tap open. The gradient was level; the train was running at the rate of 49.9 miles per hour when the brake was applied. The result was that 54 seconds were occupied in stopping the train in a distance of 807 yards. In the second experiment the same means were used except reversing the engine; gradient 1 in 330 up and level; speed 49.9 miles; time occupied, 60 seconds; distance run, 843 yards. In the third experiment when the engine was reversed, the regulator was allowed to remain open all the time; gradient 1 in 220 down; speed, 52.5 miles; time occupied, 55 seconds; distance run, 867 yards. In the final experiment all available means were used. When reversing the engine the steam was first shut off, then the lever was pulled into back gear, and then steam was turned on again as in first experiment; gradient, level; speed, 52.5 miles; time, 50 seconds; distance run, 787 yards. Captain Tyler, in his report to the Board of Trade, states that the engine-driver of the mail train, who at present awaits trial on the charge of manslaughter, could not have acted so promptly as those who on the experimental train listened for the word of command. He adds that instead of 400 yards 800 yards should have been stated as the distance in which, with the assistance of the guard, he could have stopped his train.—*Engineer.*

ENGINEERING STRUCTURES.

New Ship Canal for St. Petersburg.—St. Petersburg without being itself fortified, occupies, from a military point of view, a very fovorable and safe position, it being bounded on the land side by large impassable marshes, while on the side of the sea it is protected by water of a very small and changeable depth, no war ships of size and draught being able to enter St. Petersburg from the Gulf of Finland. It will be remembered that in the Crimean war the fortifications of Cronstadt, not on account of their excellent condition, but because of their being surrounded by very shallow and changeable water, were sufficient to prevent the combined English and French fleet from entering the harbor of St. Petersburg.

These circumstances, however favorable from a military point of view, are the cause of great and constant inconvenience, and considerable expense. No large mercantile vessel can convey its load direct to St. Petersburg, and this circumstance is so much more to be regretted as the River Neva itself offers no obstacle whatever to navigation, it having on its course through St. Petersburg a depth varying from 14 ft. to 53 ft.

As in the case of the mouths of most large rivers, the Neva has formed in the course of centuries enormous sand-banks, which still further enlarge through constant heavy west winds, offer great difficulties to navigation. These sandbanks reduce the depth of water in the different arms of the Neva to from 7 ft. to 8 ft., thus preventing ships from entering the river itself, which, as we have said, is sufficiently deep.

Some time ago a company was formed under the leadership of Mr. Kutiloff, to avoid these obstacles, and with the intention of constructing a harbor in the immediate neighborhood of St. Petersburg, it being proposed to connect this harbor with the deep water of the Gulf of Finland, near Cronstadt, by a canal.

According to the project of Mr. Kutiloff, this canal is to be built with a width varying from 260 ft. to 660 ft., and with a constant depth of 20 ft., while it is intended that the material cut out from this canal shall be utilized in filling up the marshy islands and in forming the harbor and dock arrangements at St. Petersberg.

The length of the canal will be about 16.4 English miles, and the cost has been calculated at £1,400,000. The material to be removed will amount to about half a million cubic yards. The dredging is expected to give much trouble on account of numerous large blocks being met with in this bay, the removal of which will incur much expense and trouble. The whole amount of earthwork to be removed for the harbor and canal is calculated to be about 60 million cubic yards, and the time for completion as five years. Considering that in the Russian climate only about 105 days per year can be counted as working days for this class of work, a daily amount of 18,000 cubic yards of material will have to be removed, if the work is to be completed in the stated time. The cost of excavating the harbor has been estimated at £1,200,000, the cost for a connecting canal between this harbor and the Neva, at £300,000, the railway to connect the harbor with the principal Russian lines at £300,000, and for other purposes, buildings, stores, &c., £800,000, making a total of £4,000,000. If, however, as is very probable, it is necessary to build a railway bridge over the Neva, another £800,000 will be added to this cost.

The importance of these improvements to the mercantile position of Russia will be best understood by referring to the losses caused by unloading all ships at Cronstadt. According to a recent statistical report the cost of unloading large vessels, reloading the goods into smaller ones and transporting the latter to St. Petersburg, amounts to about £1,137,500 per annum, not counting a large amount of damage and delay caused by reloading the goods.

The importance of this undertaking for commercial transactions has so fully been appreciated by the Government, that the latter has decided to undertake the construction and cost of the canal, leaving the harbor arrangements, and all connected with these, to public enterprise only.

Part of these works were opened for competition last autumn, and Mr. Elim H. D'Avigdor sent a tender for the firm of Antonio Gabrielli and Co., contractors, to the authorities of St. Petersburg for the complete work of the canal. After these works, however, had been given to the Russian contractor, Mr. Pontiloff, Mr. D'Avigdor was requested to examine and report upon the plans and estimates, and according to this report, several alterations and improvements will have to be made in the proposed details. The cross sections of the canal, as well as the pierheads on the entrance dams, will require considerable modification, the slopes of the former being in all probability too steep; these alterations will, of course, also increase the cost of the undertaking. For the information on this subject we are indebted to Mr. D'Avigdor.

It is to be hoped that the Russian Government will give all possible support to this beneficial undertaking, and have its own share of this work carried out with the utmost speed and energy, because, with the constantly increasing mercantile importance, and the unfavorable climatic conditions, this is a question of very great importance. By means of suitable steamers this small "water-street" may be kept open throughout the winter, and an easy and constant communication thus secured between St. Petersburg and Cronstadt.—*Stummer's Ingenieur.*

ORDNANCE AND NAVAL.

Hydraulic Machinery for Artillery.—A series of interesting experiments have just taken place on board the "Thunderer," turret ship, off the Isle of Wight. Some patent hydraulic machinery, invented by Mr. Rendel, and from Sir William Armstrong's factory, was on trial. By the machinery, the gun-turret was revolved, and the two 38-ton guns within it were elevated, depressed, loaded and moved in and out. The total weight of the turret with the two guns and carriage is something like 330 tons. Fifty rounds were fired; and the trial is reported to have been highly satisfactory.

Bremner's Steam Steering Screw.—Unfortunately more than one fearful catastrophe has of late directed our attention towards the want of an efficient means of turning and manœuvring vessels, for this branch of naval architecture has, we are sorry to say, by no means kept pace with the rapid strides which have been made in other studies of the profession. The introduction of long ships into the royal navy first brought home to naval architects the feebleness of the power of the ordinary rudder over such ships as the Minotaur and Bellerophon, and the balanced rudder

was introduced, by which a greater area of rudder surface could be employed at the same expense of manual labor necessary to put over the ordinary rudder. The advisability, however, of using some further power besides the rudder in order to insure quick manœuvring was pointed out by Mr. Barnaby in 1863, when he proposed the adoption of a transverse steering screw, some 10 ft. in diameter, placed in the bow of a ship, for he thought that if such a screw were connected with a small engine on the deck or in the forehold, there would be no difficulty in driving it at a speed of eighteen knots per hour, and that thus both increased speed in turning and the means of turning on a pivot from rest would be obtained. In the following year the Astronomer-Royal also brought forward the subject of a transverse screw in a paper he read before the Institution of Naval Architects, and particularly pointed out the benefit which would accrue from its use in ships of war when engaged in line or lying head and stern, as our ships were at Kertch, and when it is desirable for the precision of fire that a vessel should be so steady that the guns may be trained by marks on deck, since these are the circumstances under which it would be of the greatest importance that there should be a power, independent of the motion of the ship, of swinging her round. The method which Professor Airy proposed was a transverse screw placed in a tunnel, so that when it revolved it would pull in the water from one side and project it from the other, thus making, in fact, a jet propeller, and this plan was afterwards tried in the Hooper telegraph ship, by Sir W. Thomson and Professor Fleeming Jenkin, but as they placed their tunnel a distance of 50 feet from the stern of the vessel in a well, it failed to gain sufficient leverage—in fact, only churning water. This failure brought transverse screws undeservedly into disrepute, for on investigation it will be seen that they had hitherto failed for want of being properly applied in a practical manner. There can be no doubt that, if rightly applied, the greatest benefit would accrue from their employment, and this desideratum has apparently been arrived at by Captain Bremner. Captain Bremner has had the failures of others before him as a guide "how not to do it," and appears to have taken very great pains to arrive at the proper method of application. Still there is no doubt that these previous failures will have prejudiced the minds of many people against transverse screws altogether; but we venture to think that when they examine Capt. Bremner's plan, they will at once see its peculiar advantages. It will be seen that Capt. Bremner places his transverse screw in the extreme after dead-wood of the vessel, as low down as possible under the line of the main screw shaft. He works it by steam power by means of shafting geared on to the boss of the screw, this shafting being placed either vertically or parallel to the main shaft, according as may be most convenient. This position is now allowed by practical men, and certainly seems, to be the right one for placing the screw; for, with the same leverage as is obtained at the bow of a vessel, there is the additional advantage of the screw being fed by the water thrown back from the face of the rudder, which would naturally be put hard over whenever it would be necessary to use the transverse screw either under sail or steam, and, of course, when the vessel was stationary there would not be the same fear of the water slipping past the screw as there might be when she was under weigh. A vessel provided with a screw of this description, working well, would gain incalculable advantage in making her way through a crowded roadstead, or into such docks as those at Southampton, where the entrance is narrow and intricate, and where now it is necessary to spend a long time in warping in. The wonderful benefit, too, which such additional power would be to vessels when under imminent risk of collision need hardly be enlarged upon. The case also of the Bessemer running into the pier at Calais is one in which we believe such a contrivance as the steam steering screw would have made all the difference, and enabled her to make that most difficult harbor at slow speed in safety. Calais harbor is about 110 yards wide, and though inside it the water is comparatively smooth even on a very rough day, the tide runs like a sluice just outside it, and at right angles to the entrance, and, consequently, when a long vessel has got half in and half out of the harbor, the after end is caught by the tideway and slewed round, thus turning the bow right into the pier, in the manner which will be well remembered by all those who were on board the Bessemer on the occasion of her memorable trial trip. Had, however, that unfortunate vessel been fitted with an efficient transverse screw, we feel no hesitation in affirming that the result would have been very different. We understand that the Bessemer is still for sale, and it is evident that unless something is done to improve her, she is likely to remain a drug in the market. We have already suggested that her swinging cabin should be taken out of her, as we look on it, in its present form, as a device which can never be made successful; but her steering power must also be improved, and this, as we have pointed out, we think could be effected by means of Bremner's steam steering screw, and if these alterations and improvements are made in her, we may yet hope to see her doing good work between England and the Continent.

The cases of collision which have recently brought the vessels of the royal navy so prominently into public notice, have also shown how desirable it is that they should possess some auxiliary power to assist them in turning, not only to avoid collision, but also to escape from the ram of an enemy. There is no doubt that if ramming is to be the greatest object in future warfare, the handiest vessel will necessarily have the chief advantage. But as ramming is only a matter of close quarters, the effectiveness of the guns is also a matter of the highest importance. Now, the turret system was introduced in order to enable a ship to bring her guns to bear on her opponent with a maximum of effect and minimum of danger to herself. Since, however, turrets have in our cruising iron clads given way to broadside batteries, the necessity of having additional power

to turn the ship herself quickly is still more imperative. Much stress has been laid on the power of twin screws to assist the rudder in turning and manœuvring vessels, but, as we remarked recently, when dwelling on the loss of the Vanguard, very grave objection exists in the use of twin engines in ships of war, on account of the necessity when they are employed of doing away with the wing passage bulkheads, which curtail so much of the space they require.

As we have already stated, the application of a transverse steam steering screw was proposed by Mr. Barnaby before the introduction of the turret system, and we understand now that the authorities at Whitehall have again turned their attention to the matter, and that Captain Bremner's plan has been received with much favor. We may, therefore, hope to see a trial made with one of these screws before long, and if the results prove as good as is anticipated by the inventor—who claims to be able by this means to turn one of our longest ironclads in four minutes—there is no doubt but that we shall have placed at our command a steering apparatus of the greatest service both for peace and war.

BOOK NOTICES.

Notice sur la Marine a Vapeur de Guerre et de Commerce, par L. E. Bertin. Paris: Dunod. For sale by D. Van Nostrand. Price, $2.00.

This work is divided into two parts, the first treating of General Principles of Naval Architecture; and the second of The History of Steamship Navigation.

The author deals only in historical notes and technical descriptions. It is a convenient compend of present knowledge of steamships.

Elements of the Differential and Integral Calculus. By Prof. C. P. Buckingham. Chicago: S. C. Griggs & Co. For sale by D. Van Nostrand. Price, $2.00.

This is a text-book for beginners in calculus, and the author has given an unusual amount of space to the elucidation of the first principles.

The details of the method of presentation seem to be the author's own; the general plan being founded on that of Sir Isaac Newton, without use of infinitesimals or limits, and by reason of the fullness of the elucidation of first principles, appears suitable for students working without an instructor.

A Manual of Electro-Metallurgy. (Fifth Edition.) By James Napier, F. R. S. E. For sale by D. Van Nostrand. Price $3.00.

This excellent manual is widely known. The first edition appeared in 1851. The new editions have steadily kept pace with modern discovery, and the work has thus won a prominent place as a standard for the practical worker. The relative merits of all the ordinary forms of battery are clearly and concisely set forth. The practical uses of galvanism are placed first, and the theoretical considerations occupy but small space.

Among the additions to the former books we notice the description of the magneto-electric engines.

How to Build Ships: An Essay upon the Weakness of Large Iron Steamships; with Recommendations for making them Strong. By a Seaman. New York: D. Van Nostrand. Price, 75 cents.

The writer of this Essay is evidently a seaman of wide experience, and possessing in a high degree the instincts of an engineer. The essay is presented in three parts: the first treating of deficiencies in present modes of ship construction; the second is devoted to recommendations of methods for the cure of such faults, and the third is supplementary, so far as matter is concerned, to the second part.

The work is eminently practical in its suggestions, and is still free from unfamiliar nautical or ship nomenclature; fulfilling the promise in the introduction that "technical phrases, except those that are generally well understood, are not introduced, nor mathematical forms or inquiries. The object in view is to present a solution of the difficulties that seem to surround a very important industry, in a manner that can be easily comprehended by the man of business, as well as by the man of practice and the student of science."

Report on the Compressive Strength, Specific Gravity, and Ratio of Absorption of the Building Stones in the United States. By Q. A. Gillmore, Lieut.-Col. Corps of Engineers, Brevt. Maj.-Gen., U.S.A. New York: D. Van Nostrand. Price, $1.00.

The eminently practical character which renders Gen. Gillmore's published works so valuable to the working engineer is in no case more manifest than in the present work.

We have here in tabulated form the results of careful experiments upon all those properties of building stone which are of use in engineering structures.

The methods followed in each line of experimenting are minutely described, and where an original plan is followed the reasons therefor are fully given.

We make an abstract of the author's discussion on modes of experimenting on compressive strength:

"No one can doubt the usefulness of experiments to obtain the crushing and tensile resistance of cast or wrought iron, or steel. But having these—the compressive and tensile strengths of cast iron, for instance—and combining them together to calculate the strength of a rectangular beam, we should find on testing the beam that we had wasted a large amount of material, and that it was much stronger than the results obtained by calculation indicated. Besides, therefore, the abstract knowledge of crushing-strength which we possess, we must also, by some series of experiments, combine these and other relations so as to learn whether, as in the case of beams and columns, there may not be new forces born of the combination, an acquaintance with which would materially add to our constructive power.

"Connected with our subject, and therefore

of special interest, is the discussion made by Mr. Hodgkinson in regard to the breaking of short prisms for the purpose of finding the exact crushing-resistance of cast iron. Discovering in his earlier examinations that when these were shorter than their sectional diameter they resisted to a far greater extent than the metal could do as used practically, he thenceforth ignored such tests, beyond the simple fact of their existence, and confined his trials to prisms having a height of one and one-half the diameter or more, *because there the material gave way by the same laws, and in the same manner, as it does when used to guard human life, or secure valuable property.* In these trials he first discovered the angular breakage of material, and the law of constant direction, under the same conditions.

"In making experiments on stone, it would, from the different nature and uses of the material, be evidently improper to follow blindly the modes used for cast iron. Here are no flanged girders or hollow columns to form culminating points of inquiry. Yet in principle we have the same necessity for reasoning directly towards the end to be ultimately attained, to watch carefully the character of the material, its mode or modes of yielding, the uses to which it is daily put, the peculiar stresses and strains which come upon it, and all this, not as an individual stone which our curiosity has induced us to investigate, but as the integral part of some vast natural structure taken down little by little, and transformed into smaller artificial edifices.

"In regarding the idea of a crushing-force, the mind is too easily led to conceptions of vertical lines of strain, reaching directly from the weight at the top to the foundation at the bottom. It need hardly be said to engineers that such strains have existence only in the pages of mathematical applications, and could only be possible under the hypothesis of a film of material only $\frac{1}{5000000000}$ of an inch, or one molecule thick. So soon as another film is superadded, oblique arangements of molecule and strain would intervene under pressure, and tangential stresses would be developed. If this were not true, there would be no such phenomena as angular breakage, spreading under weight, nor any need for bond on masonry, but blocks of stone, or brick, or any materials, piled vertically one upon another, would, under a destructive load, be gradually compressed into a smaller volume, *within the limits of their original horizontal dimensions.*

"In good masonry, in which the strength of the structure depends upon material and bond, stones should never be used of greater height than the breadth of the bed. Our experiments, then, unless we should purposely test for columnal strength, would not be made on objects over a cube in height. But earlier experiments showed that the cube gave quite sufficient opportunity for the natural angular breakage of stone, and subsequent trials with homogeneous kinds prove that, while slabs less than a cube in height, pressed by unyielding surfaces, gave much greater resistance than cubes, those higher than the cube to the limit of nearly three times the width were but little if any decreased in resistance by increased altitude. The cube, therefore, was the form depended upon for specimens; a determination carried out with greater satisfaction from the knowledge that other experimenters with stone had, for perhaps other reasons, arrived at the same conclusion."

We shall make fuller extracts in a future article.

IVESON'S HORSE-POWER DIAGRAM. London. For sale by D. Van Nostrand. Price, $4.25.

Under the title of a "Horse-Power Diagram," Mr. T. G. Iveson has produced a very useful office companion. It consists of a diagram admirably engraved by Mr. Thomas Kell, mounted in a folding cover and accompanied by some explanatory letter-press, pointing out its objects and the manner in which it is to be used. The diagram, which consists of straight lines only, enables a number of calculations to be made by simple inspection and measurement by scale. Thus, given a certain size of cylinder, speed of piston and mean effective pressure (or initial pressure and ratio of expansion), the horse-power can be obtained almost at once. Similarly there can also be calculated the steam consumption in cubic feet per hour, the water consumption corresponding to the quantity of steam at different pressures, and a variety of other problems which have to be constantly worked out by those engaged in designing steam machinery. The diagram has been drawn with very great care, and so far as we have tested it, it is very accurate. The letter-press which accompanies the diagram might, we think, be improved, and the use of the diagram be more clearly explained. There is, however, nothing very complex about the use of the diagram, and a very short examination of it will be sufficient to enable any draughtsman to understand its principle, and render himself familiar with its use. As a contrivance calculated to save much time, Mr. Iveson's diagram is well worthy of a place in every drawing office where steam engines are designed.

THE NEW GUIDE TO THE LOCAL MARINE BOARD EXAMINATIONS FOR ENGINEERS FOR CERTIFICATES OF COMPETENCY; AND FOR MASTERS AND MATES FOR CERTIFICATES IN STEAM. By JOHN TURNBULL, Jr. Glasgow: James P. Forrester.

Last year the Board of Trade issued to the different Examining Boards a new series of 188 questions for use in the examination of candidates for certificates of competency, each candidate having proposed to him eight of these questions selected at will by the examiner. To these 188 questions, Mr. Turnbull has drawn up concise answers, and these answers form the chief contents of the book before us. Each answer forms a paragraph complete in itself, and the whole have been prepared with great care. In his preface, Mr. Turnbull very properly recommends that students should study the larger works treating in detail of the subjects to which his answers relate, and it is indeed evident that these "answers" are in no way intended to replace treatises on steam engineering. They are, however, calculated to

form a valuable aid to those preparing for a local marine board examination. Mr. Turnbull's volume also includes in its contents the Act of Parliament relating to engineers' certificates, and the official notices of the Board of Trade regarding such certificates. The book is altogether a very useful one for the classes for which it has been written.

The Relative Merits of Simple and Compound Engines as Applied to Ships of War. Prize Essay. By Neil McDougall, A. I. C. E., &c. London: Griffin & Co., 1875. For sale by D. Van Nostrand. Price, $2.25.

The essay, including an appendix dealing with the well-known United States inquiry carried out by Mr. Loring and Mr. Emery, with the ships, Bache, Rush and Dexter, is published in the form of a thin octavo of 87 pages; and it is due to the publishers to state that the type, diagrams, and tables leave nothing to be desired. The work is remarkably free from typographical errors, which it is almost impossible to keep out of a technical work. The essay affords internal evidence that Mr. McDougall brought with him to the task of its preparation two admirable qualifications. In the first place, he knew perfectly what he was going to write about; and, in the second, how to write about it. In other words, he is not only familiar with all that has been done in the navy with compound engines, but he possesses a really masterly style. His English is terse, grammatical and explicit, and the way in which he has arranged his matter is so good that we, at all events, confess to being unable to suggest an improvement. It is true that our author might have said more on certain points, but then he would have exceeded the limits at his disposal. Mr. McDougall has grouped his conclusions in the following order:

"First, the great aim in designing machinery for ships intended to fight under modern conditions being to obtain maximum security against disaster under fire, with minimum complexity of parts, the compound engine at its best is altogether inferior to the simple engine in this respect. Secondly, the economy of the modern compound engine is due to the use of high steam pressure. Thirdly, there is no insuperable difficulty in the way of working simple engines at the same pressure as that in use at present with the compound engine at sea. Equal economy might then fairly be expected with the simple engine, specially fitted, as with the compound under ordinary conditions. Fourthly, even if this was not the case, it would still be safest to use the high-pressure simple expansive engine under the present system of ship and boiler construction in use in this country. Fifthly, all available evidence goes to show that it is impossible that the compound engine can be to any serious extent superior to the rival engine at present pressures in point of economy."

MISCELLANEOUS.

Pencils have lately appeared, the writing of which is capable of being copied, more or less perfectly, in the press. They are said to be made of a mixture of graphite, kaolin and blue violet aniline. The graphite is used in the form of a thick paste, the kaoline in a finely pulverized state, and the aniline in the form of a very concentrated aqueous solution. The whole when well mixed is moulded under the press with cylinders about four inches long and of the required diameter. Gumarabic may be substituted for the kaolin.

A novel method of propelling canal boats has lately been introduced in Belgium, as follows:—The towpath is laid with a single rail, weighing some 16 lb. to the yard, and fixed on traverses a little more than three feet apart. The locomotive has four wheels, two of which are placed directly along the axis of the vehicle, one in advance of the other, and the others one at either side. The first pair are directing and the second driving wheels. The directing wheels are grooved and fit the rail; the others have rubber tires, which give purchase on the macadamised road, and which press thereon to the extent of 0.07 lb. to the square inch. By means of a simple mechanism, the weight of the machine may be thrown upon either the driving or directing wheels at will. In the former case the maximum and in the latter the minimum, of adherence is obtained, to suit the conditions of a loaded or an empty boat. There is but a single road, with rotary engines provided at suitable distances. Each locomotive tows one boat; and when a meeting takes place of two travelling in opposite directions, the engines change boats and retrace their paths. The locomotives weigh four tons each, and travel about three miles an hour, with full boats carrying a cargo of 150 tons each.

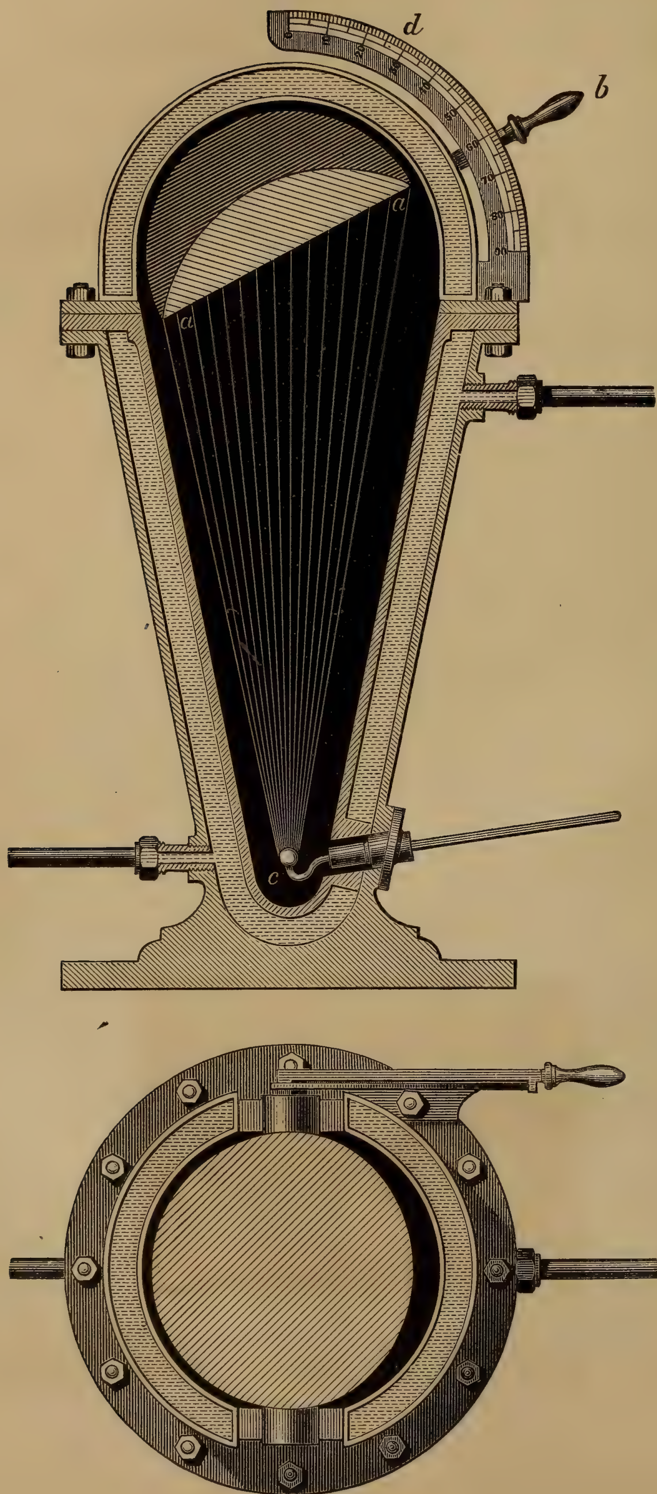
Japanese Variegated Foil.—Professor Liegg, of Japan, writes to Europe to describe a process used by the Japanese in the production of a metal leaf used for decorative purposes. Thirty or forty thin plates of gold, silver, copper, and various alloys, are laid one over the other in a given order, and soldered together at the edges, so that the whole forms a stout plate of metal. Punches of various shapes, conical, pyramidal, with triangular, square or pentagonal sides, are now used to make a pattern of perforated figures, which exhibit on their inner sides concentric circles, triangles and other forms, corresponding to the punches used. The plate so prepared is hammered and rolled until it has become quite thin, the holes disappear, and the figures have spread out, preserving, however, their parallelism. A number of broken, straight and curved lines are thus produced, which, as in a Damascus blade, are free of each other, though consistent in themselves in the same metal, their effect being further enriched by the use of acids to modify the colors. It will easily be understood that thin plates prepared in this way, having an extremely flexible nature, admitting relief, with stamped or engraved designs, and capable of receiving the most various colors and forms, will have many uses in decorative art.

Instrument for Measuring Radiant Heat Emanating from Inclined Incandescent Discs.

by CAPTAIN JOHN ERICSSON.

[SEE PAGE 194.]

FIG. 2.



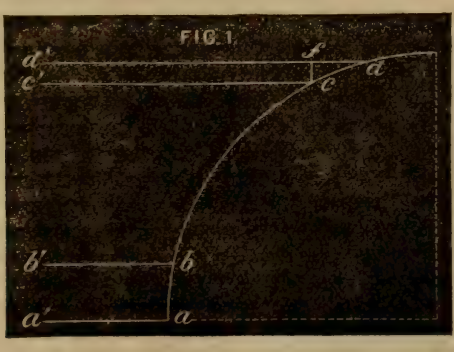
VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. LXXXVII.—MARCH, 1876.—VOL. XIV.

THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE.

By Capt. J. ERICSSON.

Previous to undertaking a systematic investigation of the above subject, I examined thoroughly the merits of Laplace's famous demonstration relating to the absorptive power of the sun's atmosphere, proving that only $\frac{1}{12}$ of the energy developed by the sun is transmitted to the earth. The demonstration being based on the assumption that the sun's rays emit energy of equal intensity in all directions, my initiatory step was that of testing practically the truth of that proposition. It has been asserted that Laplace did not propound the singular doctrine involved in such a proposition, I therefore feel called upon, before proving its unsoundness, to quote the words employed by the celebrated mathematician (see *Méchanique Céleste*, Tom IV., page 284). Having called attention to the fact that any portion of the solar disc as it approaches the limb, ought to appear *more brilliant*, because it is viewed under a *less angle*. Laplace adds: "Car il est naturel de penser que chaque point de la surface du soleil renvoie une lumière égale dans tous les sens." Let $a\,b\,c\,d$ in the annexed diagram, Fig. 1,



represent part of the border of the sun, and $b\,a$, $c\,d$, small equal arcs; $a\,a'$, $b\,b'$, $c\,c'$, $d\,d'$, being parallel rays projected towards the earth. Laplace's theory

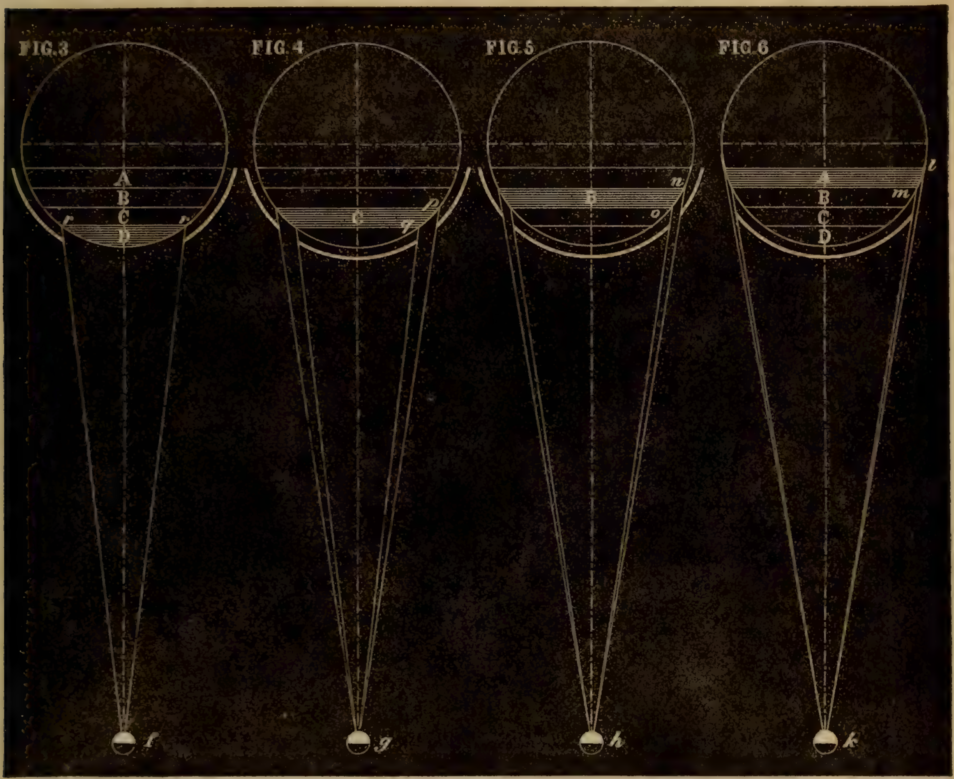
asserts that owing to the concentration of the rays, the radiation emanating from the portion *d c* transmits *greater* intensity towards the earth than *b a*, in the proportion of *c d* to *f c*. The proposition is thus stated *in Méchanique Céleste*: "Call θ the arc of a great circle of the sun's surface, included between the luminous point and the centre of the sun's disc, the sun's radius being taken for unity; a very small portion *a* of the surface being removed to the distance θ from the centre of the disc, will appear to be reduced to the space a cos. θ; the intensity of its light must therefore be increased, in the ratio of unity to cos. θ."

In order to disprove the correctness of the stated demonstration, I have measured the relative thermal energy of rays projected in different directions from an incandescent metallic disc, by the following method:

Figure 2 (see plate) represents section of a conical vessel covered by a movable semi-spherical top, the vessel being surrounded by a jacket through which water may be circulated. A revolving circular disc *a a*, composed of cast iron, the back being semi-spherical and protected by fire-clay, is suspended across the top of the conical vessel, supported by horizontal journals attached at opposite sides. The angular position of the disc is regulated by a radial handle *b* connected to one of the journals, the exact inclination to the vertical line being ascertained by means of a graduated quadrant *d*. An instrument *c* capable of indicating the intensity of the radiant heat transmitted by the incandescent disc, is applied at the bottom of the conical vessel. The mode of conducting the experiment is extremely simple. The movable cover and its lining of fire-clay having been removed, the cast iron disc is heated in an air-furnace to a temperature of 1,800° F. It is then removed by appropriate tongs, and suspended over the conical vessel, the lining and cover being quickly replaced. The temperature shown by the instrument at the bottom of the conical vessel resulting from the action of the radiant heat of the disc, is then recorded for every tenth degree of inclination. The investigation, it may be briefly stated, shows that the temperatures imparted by radiation to the recording instrument, is exactly as the sines of the angles of inclination of the disc. Hence, at an inclination of 10 deg. to the vertical line, the temperature imparted to the thermometer is scarcely ⅙ of that imparted when the disc faces the thermometer at right angles; yet in both cases an *equal amount of surface of an equal degree of incandescence*, is radiating towards the instrument! Laplace, and his followers, have evidently overlooked this important and somewhat anomalous fact, proving that radiation emanating from heated bodies is incapable of exerting full energy in more than one direction. Our practical experiments with the revolving incandescent disc, have thus fully demonstrated the truth of the proposition intended to be established, namely, that the rays emanating from incandescent planes do not transmit heat of equal intensity in all directions, the energy transmitted being as stated, proportionate to the sines of their angle of inclination to the radiating surface.

The next step in the investigation of solar heat, before adverted to, was that of measuring the radiant energy transmitted in a given direction by an incandescent solid metallic sphere. For this purpose I employed a double conical vessel, similar to the one represented in Fig. 2, the incandescent sphere being suspended over the conical vessel, in the same manner as the revolving disc. The nature of the arrangement will be readily understood by inspecting the annexed diagram, which represents four spheres, Figs. 3, 4, 5 and 6; each sphere being divided into four zones, A, B, C and D, occupying unequal arcs, but containing equal convex areas. Semi-spherical screens, composed of non-conducting substances, were applied below each sphere, provided with annular openings arranged, as shown in the diagram. Through these annular openings, the radiant heat from the incandescent zones D, C, B and A was transmitted to the thermometers *f*, *g*, *h* and *k* respectively. Père Secchi, and other followers of Laplace, will be surprised to learn that when the suspended sphere was maintained at a temperature of 1,800° F., the radiation from the zone C, Fig. 4, imparted a temperature of 27°.49 F. to the thermometer *g*, while the radiation from the zone A,

Fig. 6, imparted only 6°.19 F. to the thermometer *k*. Let us bear in mind that the radiating surface *l m* of the zone A is equal to the radiating surface *p q* of the zone C. The stated great difference of temperature, produced by the radiation from zones of equal area, furnishes additional proof that Laplace based his remarkable analysis on false premises. "The sun's disc ought to appear more brilliant towards the border because viewed under a less angle," we are told by the great analyst. The instituted practical tests, however, prove positively



that the energy of the rays projected from the border of an incandescent sphere, is greatly diminished *because viewed under a less angle* from the point occupied by the recording thermometer.

The result of our experiment with the revolving incandescent disc, shows that if the small arc *b a*, in Fig. 1, be reduced until the field represented by *b' a'* becomes equal to the field represented by *c' d'*, the radiant energy transmitted through each of those fields will be alike; the reason being that the number of rays of diminished intensity passing through *c' d'* will be as much greater than the number of rays of maximum intensity passing through *b' a'*, as *c d* is greater when the reduced $b\,a = f\,c$. It should be observed that *c d* is so small that we may without appreciable error regard it as a straight base, and *f c* as the sine of the angle *c d f*. It follows from this demonstration that if the solar atmosphere exerted no retarding influence, the radiant heat transmitted towards the earth would be alike for equal areas of the solar disc—more correctly, for areas subtending equal angles, since the receding part of the solar surface is at a greater distance from the earth than the central part.

Encouraged by the practical result of the instituted investigation, I devised the method before described, proving positively that the polar and equatorial regions of the solar disc transmit radiant

heat of equal intensity to the earth, and that the sun emits heat of equal energy in all directions. Adopting Secchi's doctrine relating to the retardation suffered by calorific rays in passing through atmospheres, viz., that the diminution of energy is as the depth penetrated by the rays, we have shown by an easy calculation, based on the result of our investigation, that the absorption by the solar atmosphere cannot exceed $\frac{1}{7}$ of the radiant energy emanating from the photosphere.

Concerning the plan resorted to by the Director of the Roman Observatory, and others, of investigating the sun's image, instead of adopting the method of *direct* observations, I will merely observe, in addition to what has already been stated, that the information contained in the several works of the Roman Astronomer, furnishes the best possible guide in judging of the efficacy of *image investigation.* Let us select his account of the investigations conducted between the 19th and 23d of March, 1852. Having pointed out that in these experiments it was impossible to approach within a minute of the edge of the sun, and that during a later observation—date not mentioned—he had approached within a minute, the investigator observes: "But at this extreme limit, even making use of the most accurate means of observation, we find difficulties which it is impossible to overcome completely." In addition to this emphatic expression regarding the difficulties encountered, the author adds: "Moreover, it is impossible to study the edge alone, for the unavoidable motions of the image do not admit of its being retained at exactly the same point of the pile; we have therefore been unable to push the exactness as far as we hoped; and we have discontinued the pursuit of these researches, although the results obtained are quite interesting." (See revised edition of Le Soleil, vol. I., page 205.) It is needless to institute a comparison between a system of which its founder speaks so despondingly, and one which enables us to push our investigation to the extreme limit of the solar disc, admitting of entire zones being viewed at once, instead of only small isolated spots.

ON WHITWORTH'S PLANES, STANDARD MEASURES, AND GUNS.

By Prof. TYNDALL, D. C. L., LL. D., F. R. S., &c.

Proceedings of the Royal Institution.

Born on the 21st. December, 1803, Sir Joseph Whitworth, to whom we are indebted for the materials of this evening's discourse, was placed at the age of fourteen under the care of his uncle, a millowner in Derbyshire. He quitted the mill at eighteen; went to Manchester, and worked there for four years, under Crichton, Marsden and Walker, and other employers. At the age of twenty-two he went to London, lived their for eight years as a journeyman mechanic, working in succession in the establishments of Maudslay, Holtzapfel, Wright, and Clements. In 1833 he returned to Manchester, rented a room with steam power, and wrote over his door "Joseph Whitworth, tool-maker from London." The ground on which his works now stand in Manchester is worth nearly a quarter of a million sterling.

His aim from the first was mechanical veracity, and his earliest step towards the realization of this aim was the production of true plane surfaces. The most accurate planes, when he begun, were obtained by first planing and then grinding the surfaces. They were never true. He abandoned grinding for scraping. Taking two surfaces, as accurate as the planing tool could make them, he thinly coated one of them with coloring matter, and rubbed the other over it. Were both surfaces true, the coloring matter would spread itself uniformly over the upper one. It never did so, but appeared in spots and patches. These

marked the eminences, which, with an appropriate tool, he scraped away. In this way he gradually rendered the surfaces more and more coincident. But the coincidence of true surfaces would not prove them to be planes. If one were concave and the other convex, they might still coincide. This was got over by taking a third surface, and adjusting it to both the others. Were one of the latter concave and the other convex, the third plane could not coincide with both. By a series of interactions and adjustments all three surfaces were at length rendered coincident; then, and not before, were they considered "true planes."

When one true plane is placed upon another, the former *floats* upon the latter, as if some lubricating material existed between them. But when one of them is slidden, with pressure, over the other, they cling firmly together. The effect is thus described and accounted for by Sir Joseph Whitworth: "If one of them [the planes] be carefully slided over the other to exclude the air, the two plates will adhere together with considerable force, by the pressure of the atmosphere." This clinging together of flat surfaces had been noticed before the time of Robert Boyle, and that great experimenter, and noble philosopher, first gave currency to the explanation adopted by Sir Joseph Whitworth. He experimented with slabs of marble, and with plates of glass, and thought he had proved that the clinging together did not occur in vacuo. This explanation was experimentally tested in the discourse. Two exceedingly accurate hexagonal planes remained adherent in the best vacuum obtainable by a good air-pump. The vacuum was still further improved by filling the receiver with carbonic acid, and absorbing the residue with caustic potash. In this way the atmosphere was reduced until its total pressure on the surface of the hexagon amounted to only half a pound. The lower plate weighed 3 lbs., and to it was attached a mass of lead weighing 12 lbs. Though the pull of gravity was here thirty times the pressure of the atmosphere, the weight was supported. Indeed, it was obvious, when an attempt was made to pull the plates asunder, that had a weight of 100 lbs., instead of 12 lbs., been attached to the lower hexagon, it also would have been sustained by the powerful attraction of the two surfaces.

To show the probable character of the contact between the planes, two very perfect surfaces of glass were squeezed together with sliding pressure. They clung, apparently as firmly as the Whitworth planes. Throwing by reflexion from the glass plates a strong beam of light upon a white screen, the colors of "thin plates" were vividly revealed. Clasping the plates of glass by callipers, and squeezing them, the colors passed through various changes. When monochromatic light was employed the successions of light and darkness were numerous and varied, producing patterns of great beauty. All this proves that, though in such close mechanical contact, the plates were by no means in optical contact, being separated by distances capable of embracing several wave-lengths of the monochromatic light.

Having obtained his true planes, Whitworth turned them to account in producing standard measures. His paper on this subject is of profound practical interest. His aim is to spread abroad notions of attainable mechanical accuracy, far in advance of his time. He pitted the sense of touch against the sense of sight,—end-measurement, felt by the fingers, against line-measurement seen by the eye,—and succeeded in proving that the millionth part of an inch was capable of accurate measurement. With instruments capable of this accuracy he produced his standard screws and "different gauges," urging impressively upon the mechanicians of his age the enormous waste which might be avoided by the adoption of uniform dimensions, capable, when accurately measured, of being accurately reproduced.

The mechanical genius of Mr. Whitworth was next applied to the improvement of the rifle. But a few preliminary words on the use of rifling may be introduced here. When a lead bullet is cut in two, a cavity is always found within, produced by the contraction of the metal. This, and other causes, render coincidence between the centre of gravity and the geometric centre of the ball the exception, and not the rule; and where this coincidence does not exist the bullet

is almost sure to quit the gun with a motion of rotation added to its motion of translation. It is then found to deviate, sometimes to the right, sometimes to the left of the true trajectory. Sometimes, moreover, it exceeds, and sometimes falls short of the proper range. The cause of this deviation was first assigned by a philosopher who made the world his debtor in two ways : firstly, by his own important original contributions to science ; and secondly, by the liberal aid and encouragement which he was always ready to extend to the younger scientific worker. I allude to the late Professor Magnus of Berlin.

Magnus's explanation of the deviation of projectiles is by no means difficult to grasp. That the deviation was produced by no shock of the projectile against the muzzle of the gun was proved by the fact that the deviation augmented in a quicker ratio than the distance from the gun. The cause of the deviation must be sought in the external air. If we blow through a tube so as to cause a current of air to pass close to the flame of a candle, the flame, instead of retreating, bends towards the current. The atmospheric pressure, in fact, is less in the current than elsewhere ; hence arises a motion of the adjacent air towards the current. If a sheet of foolscap be held with its two leaves enclosing an angle of 20 or 30 degrees, on blowing through a tube between the leaves they close up, instead of flying asunder. The old experiment of Clement and Desormes is thus explained : a tube is fixed in the centre of a perforated disk, and a second unperforated free disk is brought up against the first. On blowing through the tube the second disk is not driven away, but on the contrary held fast until the current ceases, when it falls. In this case we have a radial spreading out of the air when it strikes the free disk, and in this radial current the atmospheric pressure is so much diminished that the excess of the external pressure supports the disk.

We have now to apply the knowledge thus gained to the deviation of projectiles. Let us suppose ourselves looking down on the bullet as it quits the gun, that the axis of rotation is vertical and perpendicular to the trajectory, and that the direction of rotation is right-handed, like that of the hands of a watch. So circumstanced, the bullet will infallibly deviate to the right of the true trajectory. If, on the contrary, the rotation be left-handed, the deviation will be to the left. In one case only can the ball rotate without having this deflecting force acting upon it, and that is when the axis of rotation is a tangent to the trajectory. *It is the object of rifling to impress upon the projectile, at the outset, this particular kind of rotation.*

But whence the deflecting force, when the axis of rotation is perpendicular to the trajectory ? The ball cannot rotate without producing all round it a cyclone, by its friction against the air. On opposite sides of the bar the air of this cyclone moves in opposite directions. When such a ball passes rapidly through the air it encounters an opposing wind ; and it is obvious that on one side of the trajectory this wind coincides with that produced by the rotation of the ball, while on the other side the two winds are opposed to each other, and more or less neutralize each other. The ball will move towards the side on which the strongest currents exists, the pressure on that side being a minimum. When the axis of rotation is perpendicular to the trajectory, and horizontal, it is obvious that the proper range will be exceeded when the two currents are in opposition on the under surface of the ball, a lifting of the ball being the consequence; while the range will be too short when the currents coincide on the under surface, a depression of the ball being the consequence. Thus, by the coalescence of the wind of rotation, with the wind of translation, the deviation of the ball from its true trajectory is in all cases completely accounted for.

Prior to the year 1853 rifles had been made by hand labor. A Government Committee was then appointed to determine whether they could not be produced by machinery. The committee, after due inquiry, invoked the aid of Mr. Whitworth ; but he, lacking the special experience, and unwilling to modify his works to the required extent, declined the offer. But the subject remained open, and, on condition that a gallery should be built, where experiments as to the best form of rifle might be conducted, Mr. Whitworth subsequently

proposed to devise and construct the machinery necessary for the production of the *rifle barrel.* Lord Hardinge, then Commander of the Forces, obtained the assent of the Government to the proposed condition, and a gallery 500 yards long was erected on Mr. Whitworth's grounds near Manchester.

At the time now referred to the Enfield rifle was considered to be very near perfection. This Lord Hardinge pointed out to Mr. Whitworth, at the same time stating that any improvement which would induce the Government to change the Enfield for another rifle, must be "*very decided.*"

The powder then employed for small arms consisted of the siftings of cannon powder. The first step of Whitworth was to demonstrate its inefficiency. It was afterwards abandoned in favor of a quicker burning powder. A spiral groove within the barrel constituted the rifling of the Enfield weapon. The ball was elongated, being a cylinder with a conoidal front. Its length was 1.81 diameters of the bore. A wooden plug was inserted into the ball behind, which, pressed by the gunpowder, forced the lead into the grooves, and secured the desired rotation. The pitch of the spiral was such that to make a complete rotation the ball would have to pass through a length of 78 inches. Whitworth soon abandoned the rifling by grooves, and fell back upon polygonal rifling. He formed two accurately-fitting semi-cylinders, and having made the inner surface octagonal, with a certain amount of twist, he placed the semi-cylinders together, surrounded them by steel rings, and thus built up his first rifle barrel. It was only 10 inches long, but it beat the Enfield rifle. He lengthened the Enfield bullet, but found that fired from the Enfield barrel it tumbled over. He then passed from a twist of 1 in 78 to 1 in 30, then considered excessive, and with the augmented twist he was able to employ a longer bullet. With a thoroughness worthy of all admiration he passed in succession to obliquities of 1 in 20, 1 in 10, 1 in 5, even to 1 in 1. He thus exhausted the subject, and decided finally in favor of the hexagonal barrel, with a twist of 1 in 20. The length of the bullet was three diameters of the bore.

The performance of the new weapon astonished everybody. The School of Musketry at Hythe was then under the direction of Colonel Hay, who, in a report to Lord Hardinge, thus speaks of the Whitworth rifle: "The shooting with the gun on Mr. Whitworth's principle is truly wonderful. . . . The mean absolute deviation of the shots fired would not, if calculated, be above 0.65 of a foot at 500 yards; whereas, at the same distance, the mean absolute deviation of the best target of 20 shots I can produce, exceeds 2 feet." The tabulated results show an enormous superiority of the Whitworth over the Enfield rifle. "In accuracy of fire," says the 'Times' of April 23, 1857, "in penetration, and in range, the rival of the Enfield exceeds it to a degree which hardly leaves room for comparison." The best performance previously noticed had been a deviation of 24 inches in 500 yards. The Whitworth deviation at 800 yards was barely half this amount, while the deviation of the Enfield at 800 was more than twice its deviation at 500. At 1400 yards the Whitworth deviation was 4.62 feet, while at this distance a target 14 ft. sq. was not at all hit by the Enfield.

The lively interest manifested by Lord Hardinge in this inquiry was shared by Sir John Burgoyne. In a letter dated 11th December, 1857, he thus expresses his opinion of what has been achieved, and submits to Mr. Whitworth a new problem: "I am myself so fully satisfied with your musket as a *great* step in advance, and that I must expect it to be early adopted, that I am anxious for the time when we can know more about its powers of penetration of different substances, say iron, steel, elm, oak, &c., or earth, with the hard bullet" Never, surely, was a challenge more thoroughly met. The Whitworth rifle sent its bullets through thirty-four half-inch elm boards; the Enfield penetrated twelve of the boards, and was stopped at the thirteenth. But a totally new capacity was here manifested. The form of the Whitworth rifling permits of the use of a steel bullet, and with such bullets, at the time here referred to, Mr. Whitworth pierced plates of iron half an inch thick, not only point blank, but at obliquities varying from 0° to over 50°. I am not aware that up to the present hour any

other rifle has accomplished anything approaching to this.*

The conservative principle which resists all change, and which is so marked a feature of official life, may be a necessary element of greatness and strength to this country. It will, however, be admitted that resistance may be carried too far. The application of lightning-conductors to the fleet was officially resisted; and despite the foregoing results, which might well be regarded as conclusive, a committee of officers in 1859 reported to the Government that the bore of the Whitworth rifle "was too small for use as a military weapon." Augmented knowledge altered this opinion, and three years subsequently another committee reported "that the makers of every smallbore rifle, having any pretensions to special accuracy, have copied to the letter the three main elements of success adopted by Mr. Whitworth, viz. diameter of bore, degree of spiral, and large proportion of rifling surface." Finally, a special committee of officers in 1869 recommended the bore which had been recommended by Whitworth in 1857.

Call now to mind that Mr. Whitworth in 1854 found rifling by grooves the accepted method. This he changed for polygonal rifling. He found the twist 1 in 78; this he changed to 1 in 20. He found the rifle bullet 1.81 diameters in length; and this he changed to 3 diameters. The Martini-Henry rifle, which is now the favorite weapon, is rifled polygonally, a heptagon being substituted for Whitworth's hexagon. The twist of this rifle is 1 in 22, or almost identical with the twist of the Whitworth rifle, while the length of the bullet is 2.93 diameters, which is practically Whitworth's proportion. The Martini-Henry bullet is, however, rifled within the gun by the pressure behind it; and to permit of the employment of hard alloys of tin and lead, which it would be difficult to force into the angles of the heptagon, a sharp spiral projection accompanies the polygonal twist. This projection is forced into the bullet by the pressure from behind, and it gives the bullet the required rotation. The Whitworth bullet, on the other hand, is rifled outside the gun. Its inventor accomplishes by his steam engine the work which, in other rifles, falls upon the gunpowder; the brunt of this work, moreover, being borne by the shoulder of the marksman. The Martini-Henry rifle is unable to meet the condition deemed so important by Sir John Burgoyne, and to fulfil which steel bullets are necessary.

To sum up, when Sir Joseph Whitworth began his experiments, he was as ignorant of the rifle as Pasteur was of the microscope, when he began his immortal researches on spontaneous generation. But, like the illustrious Frenchman, Whitworth mastered his subject to an extent never previously approached. He found the power used for rifles unfit for its purpose. In point of precision, he obtained a "figure of merit" greatly superior to any previously obtained. He carried his ranges far beyond all previous ranges; and in point of penetration achieved the unexampled results which have been laid before you. He did this, moreover, by a system of rifling peculiar to himself, which had never been thought of previously, and which is substantially adhered to in the favorite weapon of to-day. It would be difficult to point to an experimental investigation, conducted with greater sagacity, thoroughness, and skill, and which led to more important conclusions.

It is the province of the generalizing faculty to extend to the largest phenomena the principles discerned in the smallest. With a directness of insight which he might find it difficult to define in words, Whitworth saw that the mechanical principles brought to bear in the infantry weapon were equally applicable to cannon. But here let me say that I am not too much influenced by the phrase "mechanical principles," so frequently employed by our great mechanician. These principles are as en-

* Both the plates and the projectiles which pierced them were present during the discourse. It is worth while to consider the condition of the bullet fired from the rifle in which the twist was 1 to 1. Half only of the ordinary charge of powder could be employed: the full charge tore the bullet to pieces. But with the half charge the bullet penetrated 9 inches of elm. A thousand feet a second would be a moderate velocity to assign to the bullet. It would travel, therefore, through the last foot of the barrel in $\frac{1}{1000}$th of a second; but in this length it would accomplish twelve rotations; hence on quitting the gun its rate of rotation would be twelve thousand a second. The rotating mirror with which Wheatstone, Foucault, and Cornu made their memorable experiments on electricity and light, rotated eight hundred times in a second. It is, however, not improbable that the Whitworth bullet had a still more rapid rotation than that here assigned to it; that it accomplished a million rotations per minute.

during as the universe, or rather as the mind which interprets the universe, when all the data have been embraced in the conclusion. But in practical matters mechanical principles, like wisdom, must be justified of their children ; and these are the tests of experiment. It is now my duty to state to you with the necessary brevity, and with such power of illustration as I can command, how the Whitworth cannon has borne the experimental tests to which it has been subjected.

Before you is a piece of armor plating 4 inches thick, manufactured by an eminent firm, with the knowledge that it was to be tested with the Whitworth gun. Beside it is an elongated, flat-headed, rifled projectile, hardly exhibiting the least mark of distortion. Yet the plate has been perforated by that steel bolt. The gun which fired the bolt was a 12 pounder ; but owing to its elongation the actual weight of the projectile is 29 lbs. This assuredly was a great achievement for so small a gun. You have seen what the Whitworth rifle accomplished with steel bullets. Before you is a series of parallel results obtained with the Whitworth cannon. The plates here presented to you have been perforated, not only by direct impact, but at obliquities of 35°, 45°, and 65°. This, to an outsider like myself, appears to be a result of extreme importance ; and the reason I say so will be immediately clear. The projectiles which did this work are flat-headed. But I have now to direct your attention to two other plates which have borne the impact of two ogival pointed shot, the one of "chilled" metal, the other of steel. Instead of being penetrated, the plates are indented merely. Fired at an angle of 45° these pointed shots glanced from the plates, scooping out a small hollow, instead of piercing them. In this experiment, the chilled shot broke up into fragments, but the steel one is intact. Taking a steel bolt in the hand, and urging the edge of its flat front obliquely against an iron plate, the bolt is arrested, because the edge cuts the plate like a chisel ; urging the pointed shot at the same obliquity against the plate, it glances off. Thus, a mere hand-experiment shows the difference between the flat-headed and pointed shot, when the incidence is sufficiently oblique. And as in actual warfare oblique incidence will probably be the rule, and perpendicular incidence the exception, this demonstrated power of the flat-heated bolt to penetrate, when the pointed shot fails, seems to me worthy of the most serious consideration.

Almost equally instructive are the experiments executed to determine the comparative power of flat-headed, round-headed, and pointed projectiles to penetrate water at an oblique incidence. The angle of depression was 7° 7′, and the length of water to be penetrated was 80 inches, the mark aimed at being 10 inches below the water line. The flat-headed projectiles appear to have gone almost directly to the mark ; the round-headed ones were tilted up and struck the plate just below the water line ; while the pointed or ogival ones were completely ejected from the water, and struck the plate at 9 inches above the water line. These are points regarding which, one would think, no uncertainty ought to exist ; they ought not to rest on the unsupported testimony of any inventor. They ought, one would think, to be tested by independent men, refuted or confirmed ; at all events, appraised at their proper value and significance.

I stand here to-night, not as the advocate of any particular system of ordnance, but in response to an expressed desire that you should be made acquainted with the physicial experiments executed in connection with this subject. To others I leave the task of deciding on the national importance of these experiments. But I claim the right, if I deem it necessary to do so, of not only presenting the facts, but of expressing the thoughts which have occurred to me during the preparation of this discourse. From all that I have read and heard, I can come to no other conclusion than that for direct impact the ogival, or pointed projectile, possesses a higher penetrative power than the flat-headed one. Hence some of the statements made by the eminent mechanician who advocates the use of the latter must, I think, appear to a severe inquirer too unqualified in their assertion of its superiority. It is demonstrably superior at the oblique incidences above referred

to; but from the comparison instituted by Sir Joseph Whitworth himself, and recorded in 'Guns and Steel,' pp. 46 and 47, it is evident that in the case of direct impact the ogival head exceeds the flat head in penetrative power. At an angle of 45° the latter clearly asserts its superiority. Hence, as the pointed head is best for penetration at an obliquity of 0°, and as the flat head is best at an angle of 45°, the thorough experimental examination would have to determine the obliquity at which both would be practically equal. The knowledge thus obtained, taken in connection with the exigencies of actual warfare, would be an important factor in the decision of the comparative merits of the two forms of projectile.

In the Preface to 'Guns and Steel' Sir Joseph Whitworth gives the following summary of his experiments on penetration:

"In 1857 I proved, for the first time, that a ship could be penetrated below the water line by a *flat-headed* rifled projectile.

"In 1860 I penetrated, for the first time, a 4½-inch armor plate, with an 80 lbs. *flat-headed solid* steel projectile.

"In 1862 I penetrated, for the first time, a 4-inch armor plate, with a 70 lbs. *flat-headed steel shell*, which exploded in an oak box supporting the plate."

(I may remark that I was present when this experiment was made, and can testify that its results astonished those who witnessed it.)

"In 1870 I penetrated, with a 9-inch bore gun, three 5-inch armor plates, interlaminated with two 5-inch layers of iron concrete.

"In 1872, with my new 9-pounder breech-loading gun, and a flat-headed steel projectile, I penetrated a 3-inch armor plate, at an angle of 45°.

"All these performances," continues Sir Joseph, "were the first of their kind, and were made, with one exception, with flat-headed projectiles." This exception, however, must be the important one, in which 15 inches of armor plating, and 10 inches of iron concrete, were penetrated by (I suppose) an ogival pointed shell. This, I take it, is the experiment described in pp. 51 and 52 of 'Guns and Steel.' It confirms the conclusion which I have been compelled to draw from the other experiments of Sir Joseph Whitworth above referred to. I could wish that this superiority of the ogival point, in the case of direct impact, had been more distinctly recognized; but I also wish to remind those whom I address that this is a point of detail, which in no way affects the merits of the Whitworth gun.

The tentative skill and insight which were so conspicuous in Mr. Whitworth's experiments with the rifle, are not less conspicuous in his experiments on rifled cannon. He takes the various elements of the gun in succession, and determines for each its condition of maximum efficiency. As before, he pushes his experiments through a range of variation so wide as to embrace both sides of this maximum. In 1856 he demonstrated that a rifle bullet should be 3 diameters long. "The rule," he affirms, "holds good for a 35-ton gun, as well as for a rifle." His experiments on the relation of the amount of twist to the length of the projectile are in the highest degree interesting. Projectiles varying from 1 to 7 diameters in length, yielded the following results:

"With one turn in 10 inches, all the projectiles went steadily with the point first.

"With one turn in 20 inches, the projectile became unsteady when more than 6 diameters in length.

"With one turn in 30 inches, it fell over when more than 5 diameters in length.

"With one turn in 45 inches, the projectiles turned over, end flew very wild, when more than 3 diameters in length."

The conclusion drawn from these experiments was, "that unless a gun be rifled with a quick pitch, so as to give a high rotation to the projectile, it would not be possible to fire long projectiles." With a sufficient twist, Mr. Whitworth succeeded, in 1856, in firing projectiles 10 diameters in length, and weighing 150 lbs. For range, the best form of projectile has a conoidal front, a slightly tapered rear, and is from 3 to 4 diameters long. With high elevations, the flight of such a projectile may exceed, by a mile, that of one with its rear untapered.

The greatest range hitherto obtained was reached at Shoeburyness in 1868.

It amounted to 11,243 yards, or nearly 6½ miles. The angle of elevation was 33°; weight of gun, 14 tons 8 cwt.; bore, hexagonal; major diam., 9 inches; minor diam., 8.2 inches; pitch, 1 turn in 165 inches; weight of shot, 250 lbs.; length, 24.5 inches; powder charge, 50 lbs.

The possibility of attaining so great a range depends on the weight and cross-section of the shot. Were there no atmospheric resistance, the range would depend solely on the velocity of the projectile on quitting the gun. But if two projectiles, one possessing a greater transverse section than the other, start with the same velocity, the thicker bolt, encountering greater resistance, is brought more rapidly to rest. The velocity at starting may be even greatly in favor of the thicker projectile, while at long ranges it is left behind.

And here we are met by one of those practical reflections which force themselves upon the thoughtful mind, and in regard to which I have already claimed liberty of expression. If the object of the artillerist be solely to throw his shot with the maximum precision, to the greatest distance, then, so far as the data before me enable me to judge, Sir Joseph Whitworth has made out a conclusive case. In the common rifle, where each bullet is intended to kill or maim a single man, these two elements of range and precision are paramount. But in artillery practice another consideration comes into play. The use of shrapnel shell is one of the most important features of such practice. In this case vastness of range is not the only thing sought. At a certain point in its trajectory—a point which the practical artillerist might fix at two, three, or four thousand yards—the projectile has to burst, and spatter a rain of bullets round it. The effectiveness of such a projectile must obviously depend on the bursting charge which it is able to carry, and the number of bullets which it is able to scatter. If—and bear in mind that I use the "if"—if the projectile be so attenuated as to diminish seriously the bursting charge and the number of bullets, then it is easy to see that while it might assert a clear superiority as regards length of range, it might be less effective than a projectile of greater diameter, at the distances most advantageous for the use of shrapnel shell. I am far from saying that the Whitworth shell is unable to fulfil all the necessary conditions; but I do say that the shrapnel shell raises a question which was not raised in the case of the rifle. And were I on a committee entrusted with the decision of this question, I should require it to be proved that the very perfection of a gun, regarded from one point of view, is not an imperfection when regarded from another. The question is one for experiment to decide; and what those interested in the establishment of the truth will be most inclined to deprecate, is the closing of the door against experiment.*

Sir Joseph Whitworth has always advocated the use of steel in the construction of guns; but without some guarantee of its trustworthiness, he could hardly have expected to convert the world to his views. It would be unreasonable to expect military authorities to make their guns of a metal which, through some defect impossible to guard against, might at any moment convert the gun into a shell, scattering ruin among those who trusted it. The onus therefore rested upon the advocate of steel, to produce a metal which could be relied on. With the tenacity of purpose, and fruitfulness of inventive skill which characterized his whole previous career, Sir Joseph Whitworth attacked this problem. The solution of it will, perhaps, be best understood by giving you an account of an experiment which I witnessed at Manchester.

Within a hollow steel cylinder, of enormous strength, were placed a series of cast-iron bars, so as to form a kind of lining. The bars were laid loosely side by side, so as to admit of the passage of a gas between them. They were also grooved, with a view of facilitating gaseous motion. The bars were coated by a porous lining of sand and other materials, through which gases could readily be driven by pressure. In the middle of the cylinder stood a core, also formed so as to permit of the escape of

* Length of range, in the case of elongated projectiles, being obtained through the diminution of atmospheric resistance; the *fighting distance* at sea becomes a point of cardinal importance in reference to this question. If this distance be great, the elongated projectile triumphs; but if it be small, a short projectile with a high initial velocity, might be preferable.

gas from it. A space of several inches existed between the inner core and outward sheath. A large ladle was at hand, and into this was poured the molten metal from a number of crucibles. From the ladle again the metal was poured into the annular space just referred to, filling it to the brim. Down upon the molten mass descended the plunger of a hydraulic press. On first entering it a shower of the molten metal was scattered on all sides; but inasmuch as the distance between the annular plunger and the core on the one side, and the sheath on the other, was only about one-tenth of an inch, the fluid metal was immediately chilled and solidified. Thus entrapped it was subjected to pressure, which amounted eventually to about six tons per square inch.

Doubtless gases were here dissolved in the fluid mass, and doubtless also they were mechanically entangled in it as bubbles. I figure to myself the fluid metal as an assemblage of molecules, with the intermolecular spaces in communication with the air outside. Through these spaces I believe the carbonic oxyde and the air to have been forced, finding their escape through the porous core on the one side, and through the porous sheath on the other. From both core and sheath issued copious streams of gas, mainly, it would seem, in the condition of carbonic oxyde flame. A considerable shortening of the fluid cylinder was the consequence of this expulsion of gases from its interior. The pressure was continued long after the gases had ceased to be ejected; for, otherwise, the contraction of the metal, on cooling, might subject it to injurious internal strains. In fact, castings have been known to be rent asunder by this contraction. By the continuance of the external pressure, every internal strain is at once responded to and satisfied, and the metal is kept compact.

The two main factors which determine the quality of any kind of steel are its strength and ductility. The method adopted by Sir Joseph Whitworth in determining these factors is, like all his mechanical contrivances, admirable. Both ends of a cylinder of a definite length and cross section are screwed firmly between two jaws, which are then separated by hydraulic pressure. For a time this stretched cylinder maintains a uniform diameter. At a certain pressure it passes its limit of elasticity, the passage being distinctly indicated by the dial which registers the pressure. From this point forward the cylinder is observed to contract at its centre, and it finally snaps across. The "strength" is measured by the breaking force; while the "ductility" is determined by bringing the fractured surfaces close together, measuring the length of the stretched mass, and expressing its elongation as a percentage of the original length of the cylinder. In one experiment made in my presence, forty seconds sufficed to stretch and break the cylinder, and there was not the slightest jar or jerk observed during the process. I entirely sympathize with the desire entertained by Sir Joseph Whitworth that these two elements of strength and ductility should be determined for, and registered upon, every ingot and bar of steel employed in the construction of our railway tiers and axles; and, indeed, on all portions of machinery the giving way of which imperils human life.

In the western mining districts of this country an unusual method of conveyance has been adopted. A wooden aqueduct, called a "flume," is constructed of triangular section, six feet wide and some three deep at the centre, requiring but slight water pressure, and following the natural inclinations or sinuosities of the district or valley along which timber has to be conveyed from the forest to the mine. At about every second mile a guardian is stationed to remove any obstructions which may occur, but although many of these flumes have been in operation for the last two or three years, some of them of a length of 50 miles, blocks very seldom occur in the passage of timber along them. They afford means of transit for foresters, who seat themselves on the floating piles of wood. Mr. Watson, Secretary of the British Legation at Washington, mentions, that in traveling through Nevada by railway he observed a snow shed or tunnel constructed entirely of timber, which it took 1 hour and 20 minutes to traverse, and which is said to be 29 miles in length.

PREHISTORIC METALLURGY.

By W. MATTIEU WILLIAMS, F.R.A.S., F.C.S.

From "Iron."

Mr. St. John V. Day, in his learned and interesting series of papers recently communicated to Iron on "The High Antiquity of Iron and Steel," endeavors to show that the art of reducing iron ores and the use of iron are of much greater antiquity that has hitherto been supposed, and also that the order of the tool-making progress of the human race has not been, as usually stated, from stone to bronze, and from bronze to iron and steel. He tells us that he has found evidence "in proof of the claims for iron to be considered amongst the earliest, if not the very earliest, of materials used by the human race," and which "negative the popular and too hastily-drawn conclusion, that man did not commence to use iron until after whole milleniums of dealing with bone, stone and bronze."

In spite of all the recent discoveries of archæologists, of Mr. Day's conclusions, of Sir John Hawkshaw's recent address, and of the comments that have been so freely made upon it, in which the subdivision of the prehistoric human progress into the stone, bronze and iron periods is treated as an old-fashioned and superseded theory, it appears to me that the balance of evidence is decidedly in favor of the conclusion that man used only stone implements long before he learned to use metals, and that, generally speaking, the use of bronze preceded that of iron and steel. I refer merely to the order of discovery and of use, without attempting any approach to measurement by years of the age and length of these periods.

The facts stated by Mr. Day and Sir John Hawkshaw unquestionably prove a higher antiquity to the use of iron than was formerly assigned to it, but we must collate these facts with the corresponding modern discoveries, which prove a vastly higher antiquity than was formerly assigned to the *début* of man upon the earth, and which antedate proportionally the stone and bronze ages as well as the beginning of iron. We now know that flint-working savages were certainly living in England during the interglacial, and probably during the pre-glacial period of tertiary geological history, that they existed here, in company with many animals that are now quite extinct. There are good grounds for supposing that they were then driven southward by the desolation of the slowly advancing ice-coat of Northern Europe, and that when the upper tertiary deposits of Asia, Africa and Southern Europe are as well explored as those of Britain, we shall know a great deal more about them. The monumental records that are quoted by Mr. Day and Sir John Hawkshaw, although of very great antiquity when compared with the age of written history, belong to what is quite the present period of the geological record ; or, restricting our view to the geological time during which man has existed upon the earth, the pyramids, the Hindoo ruins and other Oriental monuments, wherein these earliest vestiges of iron have been found, all belong to relatively modern times. The recent discoveries which push back the date of man's entry upon the world to the time of the deposition of the newer pliocene rocks, and associate him with the mastodon, the mammoth, the dinornis, the *bos primogenus*, &c., have rendered necessary a complete readjustment of our ideas and measures of antiquity. Admitting, with Sir John Hawkshaw, that the piece of iron found in the great pyramid must have lain there at least 5000 years, and that iron was made in India a few thousand years before this, we are still dealing with dates that are quite recent in comparison to the period when the bones and implements of the primitive brachycephalous Britons were buried under the glacial drift. Our ablest direct investigators of this portion of the geological record will, I believe, hold me guiltless of exaggeration or unwarrantable assumption, if I assert the strong probability of the existence of paleolithic

savages on some of the warmer regions of the earth at the time when the very site upon which the pyramids are built was a broad estuary covered by the salt water of the Mediterranean; when the deserts of Gobi and Shamo, the plains of Yarkand, Tarim, &c., were covered by the waves of a vast high-level Mediterranean, and a large portion of the plains of Hindostan, China and Mesopotamia, from which Mr. Day derives some of his ancient iron relics, were yet in course of deposition from the turbid estuaries of the Ganges, Indus, Hoang Ho, Tigris and Euphrates.

At any rate it may be affirmed with perfect safety that recent investigations have pushed back the antiquity of iron to a *great* extent, that of bronze to a *considerable* extent, and the stone period to a *vast* extent. The interval between the beginnings of bronze and that of iron may be relatively smaller than was once supposed, while, on the other hand, the duration of the stone period must have been vastly greater, as the general result of modern research is to reveal its further and wider extension and to antedate its beginnings more and more profoundly.

Although our ideas of time, our positive measurements, and the idea of equal or similar periods which the bare subdivision of human progress into three ages naturally suggests, may require rectification; nothing has yet been discovered that demands any radical change in the accepted statements of the *order* of the developments of human metallurgical achievements. There may be *gaps* in the series, but there is no *inversion.* The discovery of localities where iron implements are lying side by side with those of flint and without any traces whatever of the intermediate bronze, only shows that these places may have been uninhabited during the bronze period, or that its paleolithic or neolithic savages may have been elevated or superseded by an irruption of steel and iron sword bearers.

An exact analogy of this is presented in the geological series. Certain strata or groups of strata are wanting in many places, either because these localities were up-heaved during the epoch of deposition of such strata, or because they have been denuded subsequently. Different portions of the globe have simultaneously existed in different stages of progress, but there is no instance known of an inversion of the order of succession of life in any part of the world.

Philosophically regarded, this is the most important of all the results of geological research; it is the basis of the doctrine of evolution. The invariability of the order of human metallurgical progress has a similar interest; it is, in fact, a continuation of the same record. It shows that the human being is essentially a progressive animal—brings the great question of human progress under the domain of natural law. If it could be shown that the human race had ever gone back from iron to bronze and from bronze to flint, the general conclusions of modern science concerning the order of human development might be justly challenged in favor of the old traditional ideas on this subject.

The usefulness of bronze tools is so much greater than that of stone implements, the superiority of steel and iron to bronze is so decided, and their applications are so essential to human welfare, that a return from steel and iron to bronze, or from bronze to stone, would indicate a positive incapacity for progress, and an inherent tendency to retrogression on the part of the people capable of such return, while, on the other hand, the fact that no such return can be demonstrated is, as I have already said, the broadest and most fundamental expression of the law of human progress. Such apparent exceptions to the law of metallurgical development as the discovery of bronze surgical instruments at Herculaneum, merely shows that for special purposes the old material may have been preferred in comparatively recent times. Facts of this kind interlace the three periods in such a manner as render any broad and definite boundary unattainable, but do not reverse them. The same occurs in reference to geological periods. The discovery of living cretaceous foraminifera in the deep Atlantic, and their operation in depositing a variety of chalk at the present moment, is an illustration of this.

The manner in which a gap in the metallurgical series may occur over a limited area is instructively shown by

the present state of things in New Guinea, the natives of which, as far as their own productions are concerned, may be said to be still living in the stone age, as the bottom of the deep Atlantic is still in the Cretaceous geological period. But side by side with their own stone implements are a few hatchets and rude spear-heads, &c., made of iron scraps that the natives have obtained from their rare European visitors. They covet these so eagerly that they will exchange an elaborately carved paddle or club for a piece of old iron hoop. They have no bronze implements, not because they used iron before bronze was invented, but because the stone period was in their case so far prolonged that they only began to use iron after bronze implements were superseded. This may have occurred at other places than New Guinea and at earlier times than the present.

This curious prolongation of the stone period into the nineteenth century is a fact that should teach us to be cautious in making any sweeping inferences from the discovery of particular and exceptional monumental or other human remains. If a collection of the home-made implements of the present inhabitants of New Guinea were laid before an archæologist, with no further information than these afforded, he would make some curious mistakes in attempting to determine the period of their origin.

We are therefore justified in bringing natural metallurgical considerations, or, I may say, metallurgical necessities, to shed additional light upon the obscurities of these archæological problems.

I have already ventured to do this by showing how the natural properties and the distribution of the metals must have influenced the order of their discovery and use by man. These considerations point to gold as the first metal that would offer itself to human notice, for the following reasons:—(1) It exists naturally in the metallic state. (2) It is found upon the surface of the earth, just in those places where man would first settle, viz., on the banks of rivers and in alluvial deposits, and although only found in small quantities it is very widely distributed. (3) It is so brilliant in its native condition that it could scarcely fail to attract attention, and its malleability is such that it may be shaped by the rudest stone implements. Its discovery would of course begin with a few rare nuggets, and it would probably be first used for ornament. Savages knowing the use of fire would soon discover its fusibility, and then might collect smaller fragments or grains and melt them together.

The use of gold and the idea and valuation of metallic lustre would at once direct attention to the yellow gold-like iron and copper pyrites. Attempts to fuse the first of these would fail, but if the second were heated in a brisk wood fire it would be roasted, fused, and, more or less completely, reduced to the metallic state by the driving off of sulphur.

But why, it may be asked, should the discovery of the other constituent of bronze—the tin—have taken place so early, seeing that tin-stone has no metallic lustre and is scarcely distinguishable from ordinary pebbles?

My reply to this is that tin-stone, like gold grains and nuggets, is spread by the action of rivers upon the surface of the earth; and, although less widely diffused than gold, is much more abundant where it does exist, and is just on the banks of rivers and alluvial deposits where man would first settle. The charred wood of the kitchen middens, &c., shows that the men of the later portion of the stone period had learned the use of fire; but as their rude earthern pots and laborously chiseled stone troughs and basins would not bear firing from below, they probably adopted the well-known primitive method of boiling water by throwing into it pebbles that had been heated in a wood fire. The Chersonese or Cornish savage could not have performed this operation a dozen times—could not have cooked a single grandmother—without deoxydizing a few tin-stone pebbles, fusing the metallic tin, and finding brilliant silvery metallic buttons among the ashes of his wood fire. As copper and tin ores are usually associated, he would probably have also produced an accidental bronze in the course of his cookery. The same would occur in the tin-stone districts of Sweden, Bohemia, Saxony, Hungary, &c., in most of which nuggets of copper ore also exist among the river-borne pebbles. In

the few localities where argentic pyrites occurs superficially, buttons of silver may have been similarly obtained.

The comparative infusibility of iron would render its accidental discovery by a savage people, otherwise unacquainted with metals and metallurgy, a practical impossibility. When, however, they had so far advanced as to imitate deliberately the processes of reduction and fusion that had been discovered accidentally, and had carried on their metallurgical operations far enough to have invented some rude form of bellows to urge the fire; when they had made castings and experimented upon the properties of alloys, they would probably succeed in obtaining first a fusible sulphuret of iron, or rather sulphuretted iron, from the attractive yellow pyrites; and this product, in spite of its redshortness, would have considerable value to such people.

Once familiar with this dull, gray, semi-metallic substance, liable to become reddened on the surface by exposure to the air, the resemblance of native magnetic oxydes, of some of the hæmatites, and of specular iron ore, to it in color, semi-metallic lustre and density, would naturally lead to attempts to fuse these ores in the primitive furnaces urged by the rude bellows then in use.

What would follow such an attempt carried on with some perseverance? Nothing less than the production of a fusible, highly-carburetted cast steel, of great hardness and fine quality. With pure ores, wood fuel, and not too strong a blast, neither malleable iron, nor that grossly impure steel to which we give the name of pig-iron, could be produced. The eagerness to acquire a cutting weapon or implement, would soon lead to the discovery of the leading properties of this steel. A people already acquainted with bronze that can be hardened by heating and cooling slowly, or softened by heating and plunging while red hot into cold water, would of course try the same upon their new gray metal, and would thus discover that by opposite means it could be made capable of cutting and forging itself. This discovery of steel and subsequently of malleable iron would place in the hands of man a new element of physicial power, and one of such great value and importance that its introduction would constitute the widest stride that had yet been made in the course of human progress. It would truly open a new era, at a time when physical power was all in all, and therefore we are justified in thus describing it, and in speaking of the stone, the bronze and the iron ages as definitely and distinctly as the geologists refer to the primary, secondary and tertiary geological eras, and of the paleozoic, mesozoic and cainozoic periods of animal evolution.

Continental Coal.—The prices of coal, which tend to fall in England, are steadily falling in Germany as well, there being nothing to indicate any probability of a rise. On the other hand, the coals of France and Belgium, even for the district of Liége, have a very distinct upward tendency and show firmness. At Mons, in the coal county of Hainaut, this is more especially marked, prices having hardened, not in consequence of diminished production, but in consequence of greater commercial activity. This is partly through the abandonment by the Paris Compagnie de Gaz of German coals, which gave unsaleable coke. The Société John Cockerill has reduced its colliers' wages by 10 per cent., and the Marihaye Company has made a still larger reduction. In the Departments of the Nord and the Pas de Calais the coal-owners have subscribed 6,000,000 francs for improving the canals of two departments. The improvements will be carried out by the local administration, and will result in giving the canals a navigable depth of over 10 feet. This movement has probably been stimulated by the establishment at Paris of various agencies for Newcastle coal. In the first six months of the present year coal was imported into France to the value of 94,097,000 francs., being an increase in value upon the corresponding period of 1874 of over 14,000,000 francs. The total coal raised in the two departments of the Nord and the Pas de Calais during the first six months of 1875 was 32,120,715 metric quintals, being an augmentation over the corresponding period of 1874 of 2,600,585 quintals.

HOW THE PARISIANS BUILD A HOUSE IN FLATS.

From "The Architect."

The newspaper writers of more than one country, who used to compare Louis Napoleon to Octavius Cæsar, had at least foundations strong enough to support a superstructure more solid than a compliment. If the latter was enabled to say that he had changed Rome from a city of brick into one of marble, the French courtier who declared that the Emperor had found Paris of plaster and would leave it of stone, told a truth which neither the friends nor detractors of the Second Empire seem to have even yet completely realized. But the rearrangement and reconstruction of Paris has been proceeding gradually since the great Revolution. Much of that which was achieved by Napoleon III. had been projected by his uncle ; although even in the time of Louis Phillippe the majority of the streets had no foot pavement, and the gutter was in the middle of the roadway. In lighting as well as cleanliness the French capital was then far behind London. It is incredible to hear that thirty years ago the Parisians envied the Londoners their large open squares, their lamp posts, and their vestry-men ! To those who know the two cities as they are now, Macaulay's celebrated description of the English metropolis in his chapter on the "State of London in 1685" appears an exaggerated eulogium; but when it was written, London in all but its architecture was a finer city than Paris.

The housè in flats specially constructed for the purpose was not common in Paris until the end of the reign of Louis XIV., who died in 1715. The custom in France of building houses for the express accommodation of several families does not go back further than the seventeenth century. A birdseye view of Paris engraved upon copper in 1607 shows the cathedral towering above a number of one-story tenements ; and the churches and public buildings stand out from a mass of houses of small elevation. I am constrained to think that the intercourse then existing between France and Scotland led to the adoption in Paris of residence by floors, as it was practised in Edinburgh even by families of noble birth in the sixteenth and seventeenth centuries. Facts go to prove that the many comforts which the Parisians now obtain are of recent invention. The introduction of back staircases into Paris houses in flats dates only from the beginning of the nineteenth century ; and I think it probable that the Parisian *maison-a-loyer* only received its present developed form after the great Revolution.

The recognized authority in Europe upon this kind of habitation is M. Cesar Daly, the well-known author of books upon this and cognate subjects. He divides Paris houses into three heads according to classes of the population : 1st, The aristocracy, who live in private houses (*hotels*) ; 2nd. The *bourgeoisie* or middle class, who occupy houses in flats (*maisons-a-loyer*) ; 3rd, The working class who inhabit houses from which the two classes above them have departed. As M. Daly has poetically said that the house is the "family vestment," so, I may venture to add, the worn-out clothes of the few descend to cover the many.

Various fallacies are rife amongst Englishmen concerning Parisian dwellings, and people frequently talk about the ten-storied houses of Paris. None of more than five stories above the ground floor and a roof have been built there since the year 1784. It is popularly supposed that in Paris noblemen occupy the first and second floors of a house, gentlemen the third and fourth, tradesmen the fifth, and working men the attics ! But Paris houses are inhabited by people of nearly equal position in society, or, at least, they are so arranged by means of separate staircases, that the meaner tenants do not encounter their happier neighbors except in the open court or at the carriage entrance. It has been said that the roof to which the elder Mansard gave his name was invented to evade the laws regulating the height of buildings in Paris, but the mansarde or curb roof had been in fashion

* A paper read before the Architectural Association by Mr. W. H. White.

for 150 years before any such laws were made. From 1784 to the present day the legal height of a Paris house has depended upon the width of the street in which it was built. The facades of houses erected on the boulevarts and principal streets must perforce be composed of freestone. The floors are of rolled iron enveloped in plaster concrete, and the general application of iron to the construction of floors is due to the carpenters, who in 1840 "struck" in a body, and thus solved for their city at least the problem of fireproof construction. These floors are no man's specialty or patent. The rolled iron joists can be laid by any smith, carpenter or *macon*, and finished in plaster by any workman of the last-named trade. An order from the architect is alone necessary, and to people about to build in Paris an architect is absolutely indispensable. There are no general contractors in the French capital. On an ordinary Paris house there is rarely a clerk of the works. The foreman of the *macons* in conformity with tradition, is the head of all the workmen of all trades. In France, the *macon* is not a worker in freestone like the English mason ; he is bricklayer, plasterer, builder of rough stone walls, worker in cement of all kinds. The contractor for all these works is also entrusted with the masonry, as the word is understood in England. He erects the scaffolding, and only in large buildings is the carpenter employed in such work. All work is paid for by measurement after completion, according to a municipal tariff which varies annually and forms a basis of prices for artificers' work done within the city of Paris. The architect has to treat with, say, a dozen tradesmen, innocent of any sort of mutual organization and unwilling to accept instructions from any but their master—the master of the work. A dozen contractors imply a dozen sets of drawings, a dozen agreements, a dozen bills. The architect has to verify the items of each bill, to check the dimensions and modify the prices for labor and materials in accordance with the signed agreements and the Parisian tariff. He consequently employs a specialist (*verificateur*), whom he pays out of his usual commission sometimes as much as one per cent. ; but the architect alone is responsible to his client for the accuracy of these bills, the name of the suveyor he employs not appearing in the transaction ; and a French architect's responsibility to his client and to the State endures for ten years after the completion of the works he has superintended. I propose to describe the erection of a first-class house in flats ; with appliances which have been practically tested by myself, but the house will be a fancy picture, sketched at different times and from several examples.

The plans, sections, and elevations, are ready any lithographed for the use of the contractors and foremen. The line of frontage is obtained, and to get one's line of frontage on a Paris boulevart is a thing quite as serious as getting married or buried. The master-mason is ordered to begin, and his foremen, that is, the master-companion, marks out the trenches to receive the foundation of the basement walls. But below these are two large cubes of earth to be excavated, for the two cesspools required to drain two separate sets of water-closets—one set for the large residences, and one for the servants and a few small residences. A cesspool must be immediately under the water-closets it serves. The main drain pipe must descend vertically into it, and ascend vertically to a certain height above the ridge of the roof. A junction pipe, connected with the water-closet apparatus, enters this main a little below the level of each floor. In juxtaposition to the main is placed another pipe, which ascends vertically from the cesspool to above the roof, this pipe being used exclusively for ventilation. Both these pipes are attached to a strong wall with hoop-iron, and completely enveloped in cement. The walls, bottoms, and vaults of the cesspools must be built of *meuliere*—a species of reddish petrified sponge, and very hard. It is found near Paris, and it affords an excellent surface to receive the coat of cement with which the walls internally of all cesspools must be covered, their internal angles being rounded. From the vault of each cesspool a shaft must be formed, the top of which must communicate with the court-yard, and be covered with a stone slab fitted into a stone frame. This slab is hermetically sealed, and only opened when the cess-

pool is full; and then it cannot be refixed until the interior has been officially inspected. These cesspools are so built that the top of their vaults is on a level with the floor of the basement story. While they have been building a gang of men have been occupied at a corner of the site. They are preparing *beton* which, according to learned professors, is of Roman origin, and which I venture to say is less easily adulterated than the English concrete. In the corner alluded to a platform has been made of planks, on one side of which is a heap of pebbles and chips of stone, on the other a heap of sand, and under a shed close by a number of sacks containing hydraulic lime; and some mortar is already prepared for use. Wheelbarrows are scattered about, and the bottoms of some of these are made with iron bars to hold the pebbles, for it is necessary that these be thoroughly washed, and consequently when they are placed in the wheelbarrows the water escapes from them through the iron bars. My *béton* shall be perhaps extravagantly good; and, as is well known, *béton* is a mixture of hydraulic mortar with pebbles or stone chips from the quarries and yards about the size of an egg and similar to those used to macadamize a road. The mortar and pebbles are sometimes very well mixed by a machine, but it is better done by hand. Five wheelbarrows are required, three with bottoms of iron bars, and two of ordinary make. The three first are filled with pebbles and the two others with mortar. One barrow of pebbles is wheeled to the wooden platform, and its contents are spread out over the entire surface; above these is uniformily spread a barrow of mortar. A second barrow of stones is deposited in the same manner and a second barrow of mortar, which is then covered with the third barrow of stones. The heap is turned over and dragged with a three-pronged fork or hook; and the pudding is considered to have been sufficiently stirred when the pebbles are entirely enveloped in mortar. Before throwing the *béton* into the trenches a layer of gravelly sand has been spread over their bottom surface, which will prevent the mortar from becoming deteriorated with the soil beneath before it is properly set. There is no absolute necessity to ram *béton* if only it be carefully laid. I have ordered it to be spread in horizontal beds of from eight to ten inches thick, and I shall begin the walls upon it almost immediately. No *béton* has been put under the walls of the cesspools because the building is not to be supported upon them. There is a height of about 30 inches of *béton* under the principal walls, and when they have reached a few feet in elevation I shall spread over the whole area of the building a layer of *béton* about 10 inches thick, the top of which shall be level with the top of the *béton* under the principal walls. Thus I can support the 9 inch brick partitions to form the numerous coal and wine cellars, which occupy the whole of the basement story, for in Paris an underground story is seldom, if ever, inhabited. The walls which touch against the earth will be built of rough hard stone (*moëllons*) at least two feet thick coated externally with cement. These walls are now within a few inches of the street level; brick arches are being turned over the cellars between the partition walls, their flanks are filled up with more *béton* and a general even surface is obtained about a few inches below the finished level of the ground story. A horrible odor pervades the works. Around a cauldron two men are dancing. One stops to throw into it a lump of bitumen, then a little gritty sand, and the other stirs up its contents. Suddenly one rushes off with a saucepan full of the boiling liquid and spreads it cautiously over a part of one of the walls; then a bricklayer lays bricks hurriedly upon this same spot, blasphemes and sucks his fingers. More asphalte is brought, always in a boiling state, and eventually two courses of hard bricks are laid over the principal walls. A coat of asphalte about an eighth of an inch thick will be ultimately spread over the whole area of the ground floor, under stone, tiling or parquetry as the case may be. Above this level I have seven stories including the roof to construct, and the existence of a shop on the ground floor neeessitates as much open space as possible. The weight of the internal walls must be concentrated upon a succession of supporting points or piers which I shall build in solid blocks of hard limestone. There must, however, be a carriage en-

trance and the walls enclosing it must be of solid stone, so that the difficulty of making a house-front appear logically constructive is lessened in Paris by the fact that such entrances form an important portion of the front. The rest of the front will be surported by coupled iron columns placed between stone piers. The girders they support are of rolled iron, also coupled, and about 10 inches deep, which will suffice to carry my facade of 50 feet of masonry. These girders are secured together with wrought iron collars about four feet apart. Planks having been temporarily placed under them they will be filled with bits of broken brick, lumps of old plaster partitions, &c., and the whole "run" in fresh plaster. A solid lintel of iron and plaster is thus formed, about 18 inches thick, 11 inches deep, and from 6 to 8 feet long. Similar lintels are being placed over all the internal piers; and upon them the rolled iron joists forming the floor of the first story will be laid. These lintels will also receive the weight of the partitions of the different stories over. The completed flooring, including the ceiling and parqueting, will not exceed 12 inches in thickness. The rolled joists are placed 30 inches apart, and, at right angles to them, are fixed wrought iron bars which are bent at the ends so as to clip the upper flange of the joist and permit the bottom of the bar to be level with the lower flange of the joist. These bars are placed about 3 feet apart, and as much as possible in a straight line, for they will act as a strut. A blow suffices to fix them. Upon these bars, in lines parallel with the joists, and of the same length, light iron rods are laid. All this iron has received two coats of paint (of *minium de fer*), and the skeleton is ready to be converted into a concrete floor. A temporary ceiling of planks is erected under the iron skeleton. Upon this planking are thrown bits of old plaster, brick, and hard rubbish of all kinds until the whole space between the joists is filled up almost to the level of their top flanges. Liquid plaster is then run into and over the whole mass of iron and ballast, and the morning after the temporary planking may be removed. But this useful substance, plaster, has a tendency to swell, and if a small cavity be not left between the solid plaster floor and the stone wall, the latter will be pushed outwards. It is usual at the level of each floor to tie in the external and party-walls with iron bands looped at different points over circular iron rods (*ancres*) inserted vertically in the centre of a solid block of stone. These bands are hooked together midway between the rods. For my part I only use these ties in deference to the vested interests of the master-smith; for in spite of the usual precaution of paint the insertion of iron chains into soft limestone is a hazardous proceeding. Damp rusts the iron, which then increases in bulk and cracks the stone; or it is ultimately reduced to carbonate of iron.

The building is now at the level throughout of the first flat, which is usually called the *entresol*, and the walls have reached to within a few inches of the finished line of parquetry. The master-companion is engaged in finding the centres of his doors and windows. These centres are all marked upon the plans. He has fixed to the scaffolding outside the walls strips of deal, and tells off upon them the distance from centre to centre of the front window openings. If the walls are rectangular he tells off the same distance upon similar strips of deal fixed to the scaffolding outside the walls of the courtyard. Lines of thin cord are then stretched from one point to another, and the principal centre lines drawn as it were full size upon the works. Where these lines cut the walls he spreads upon the latter a layer of plaster; and then with the aid of the plumb line, square, and a piece of black chalk (*pierre noire*) he marks upon the plaster the centres of all openings, which marks remain until the masonry is terminated; and they serve to find the centre of the keystone in the arch over. A projecting cornice of hard stone covers the shop window lintels. The top of it forms the sills of the entresol windows, which are casements, and descend almost to the parquetry. Up to this height the stones have been lifted with slight difficulty, either rolled upon an inclined plane made of planks, or pulled up by the "*chevre*," a species of "crab." But in the meantime four tall masts, some 70 feet high, have been fixed just in front of the facade. These will be

connected at intervals with transverse planks, and further strengthened with cross pieces, the whole forming, when finished, a skeleton shaft. Within it the blocks of stone will be lifted to the height required by chains swung over a wheel fixed at the very top, the motive power being stationed at the bottom, and consisting of steam, water, or manual labor, or the last new invention—human force, however, being the most frequently employed, for in the present state of education in France it is the cheapest in the end.

The facade now being put together will be composed of solid free-stone about 22 inches thick—the blocks to be laid in the same position horizontally as they were found in the quarry. The material I am now going to lay upon the first cornice is a soft limestone, found deposited by layers and extracted in large blocks. It is not worth while to saw these blocks horizontally, even though it only requires the toothed saw to do it. The height of each course is the height of a layer of stone, for the heart of the stone ought never to be exposed to the atmosphere. The power of resistance in soft limestone to the many deteriorating influences around it depends upon the free exercise of that natural action with which it is endowed. To use it as mere ashlar facing is positive destruction to it. Soft calcareous stone easily soaks up water, but it also easily ejects it ; and, provided the action be free from the outside to the inside of a stone—provided the stone be so placed as to permit the moisture it receives from the outside to be drawn away from it in a fluid state, its component parts will not suffer deterioration. But if (as in the case of ashlar where only one side is free) the exposed face of the stone dries and leaves the heart unnaturally wet, the internal moisture—which must find a way out—will crystallize upon the surface, which will become inflated and then scale off. Damp attacking a solid stone wall from the inside of the room which it encloses is drawn from it by natural means ; but damp penetrating internally a brick wall faced with ashlar destroys the ashlar because the moisture cannot escape naturally through the stone, which, on its external surface, is dry. The fixing of one stone is but the repetition of another, and the laying of one floor resembles another. It may be supposed, therefore, that the front wall is ready to receive the principal cornice —the top of which is on a level with the base of the mansarde, and this level is about 65 feet 10 inches above the foot pavement, which is the extreme height allowed by law for a house on a boulevart of 20 metres and upwards. There are, however, means to construct one more story and an apology for another in the roof. The one will compose a floor of perhaps two residences and the other a host of small bedrooms, a few perhaps to be let separately, and the majority to be apportioned amongst the various tenants for the accommodation of their servants, both male and female. In the case of this house the outline of the roof must not overstep a quarter of a circle whose radius is equal to half the depth of the main building exclusive of the projecting top cornice. The chimney shafts must not break the sloping roof line except at a distance of 5 feet measured horizontally from the external face of the front wall, nor must they rise more than 2 feet above the ridge. The external face of the dormer windows must be set back at least 1 foot from the external face of the front wall ; and their width must not exceed 5 feet from out to out. The compulsory setting back of the dormer windows favors the construction of a broad continuous balcony over the top cornice, which causes the fifth floor of a Paris house to be much appreciated. There is also a continuous balcony for the first floor residence, which is supported upon corbels over the entresol windows, and smaller balconies of slight projection to the other windows of this house. The balconies are constructed of slabs of hard limestone, from 8 to 10 inches thick, moulded on the face, and their soffits are paneled.

Some of the modern houses are roofed with rolled iron principal and common rafters and purlins all enveloped in plaster. I intend to eschew all battens to receive the slates and lead flashings, for it has been satisfactorily proved in France that the best foundation for lead coverings is plaster. The mode of making lead terraces, without rolls or other excrescences and presently pre-

senting a perfectly even surface, has reached a high pitch of development from the exertions of M. Monduit, who, under M. Viollet-le Duc, has successfuly revived the forgotten traditions of the lead and copper beaters' art. Strips of iron of an L-shape are to be screwed to the iron rafters, and the slates will be suspended from them upon copper hooks. The lead flashings and lead "slates," where any are necessary, will also be hooked; or they will be dressed up freely under a projecting stone fillet moulding. This practice is advisable, because the extreme heat and cold experienced at different seasons in Paris have a potent effect upon the contraction and expansion of metals. Therefore none of the lead used in my roof shall be nailed or secured with cement or mastic. The dormers shall be of beaten lead, for which the crudest possible skeleton in iron has been put together, and painted. Upon this the skilled workman adjusts the different pieces of lead—ornament, moulding, or plain covering, as the case may be. He solders them together at the back and round the iron; and the dormers, finished at the workshop, have only to be packed and sent to the building, of which they form no insignificant part. In the workshops of M. Monduit I have seen workmen converting, with hand and eye alone, rough pieces of copper into human shape, from a full size drawing suspended before them.

The roof is now covered in, the party walls are covered with stone, and the chimney-stacks, faced with stone, are finished; but the facades fronting the boulevart and the courtyard have yet to be dressed and cut into mouldings, for at present the different architraves, cornices, and pediments have been merely blocked out by the ordinary stonecutters. Another set of workmen have now to shape them according to the full size drawings of the architect. All the nearly horizontal surfaces of the stone exposed to the weather, excepting the balconies, which are of specially hard material, will be covered with zinc. As the carvers aud sculptors finish, the scaffolding descends from story to story, and the architect's troubles begin. The contractors are summoned to wait upon him at the usual hour—between 7 and 8 in the morning. An appointment is given at the works in the afternoon of the same day, when the curious passer-by will probably observe a crowd of respectable and sometimes polished-looking men standing in a forest of scaffold-poles. These are the contractors. They are seldom displeased at often being kept waiting, and some doubtless wile away the time by deploring the last revolution and discussing the next. Suddenly they all take off their hats, for the architect has arrived. As he passes through the works, followed by the whole bevy of contractors and the master companion the men salute him. From the beginning to the end of a new building he is the recognized master-of the work, whose decision is final, and whose position is unassailable. And the politeness with which they treat him is increased when, as I know from personal experience, he sometimes happens to be a foreigner.

The first thing now to be done is to fix the principal staircase. This shall consist of a comparatively new combination of iron and plaster with treads of white marble and a wrought and cast iron railing, covered with an ebony handrail. An iron carriage of an L-shape is secured at the bottom to the brick vault or to a wall. The upper edge of this carriage is cut into the requisite number of steps, and at the level of the first landing it is fixed to a joint much the same as in wood construction. Each riser is a piece of thick sheet iron fixed at one end to the carriage with an angle plate and bolted, and the other end is inserted in the wall. To form the soffit, iron bars must be placed below the risers; one end of them is secured to the flange of the carriage and the other is let into the wall. Upon these bars thin iron rods are laid, and this skeleton is filled with plaster concrete in the same way as the iron floors are treated. Not alone the soffit but the section of the stairs is thus formed. Upon the latter will be placed slabs of white marble with the moulded nosing of each returned over the iron carriage. The landings are formed with iron joists, bars, and rods enveloped in plaster concrete, and this horizontal surface will by-and-by receive a covering composed of a border of white marble filled up with small cubes of marble mosaic work. The iron standards will

be fixed to the external face of the carriage; and the soffits of the stairs and landings will be finished in plaster in the usual way. The iron portions will be painted with iron minium obtained from Belgium. The staircase fixed from top to bottom—one flight being only the repetition of another—it is possible to get up to the fifth floor residences which are in the roof. To reach the upper story in the roof, where the servants sleep and stray bedrooms are let to homeless bachelors, it is necessary to take the back staircase. The fifth floor is to be let in two comparatively small residences; all the rooms will be boarded with polished oak parquetry, and only the kitchen and the passage leading to it will be tiled. In walls of one brick or more thick, the door-frames are fixed with cramps or rather staples (*pattes*) against the face of the wall. These staples are of iron screwed at one end to the wood door post, and at the other split into claws which are inserted into the wall and fixed with plaster. On the opposite side of the wall an oak architrave, plain, and as thick as the plaster coat, is fixed in the same way against the brick. The reveal is finished with plaster. The junction of the wood and plaster where the two are flush is concealed by wood mouldings. In no part of a Paris house are there any wood lintels. In the half-brick partitions the door frames are in wood of the same thickness. In a solid stone wall the arch over a window opening is made through the whole thickness of the wall, and the rebate to receive the casement frame is cut after the building is covered in. The frame is fixed in this rebate with iron staples and plaster. In a one-brick wall the openings are covered with iron bars enveloped in plaster. The ceilings and cornices will be much more artistically finished than people are accustomed to see in England; and descending from floor to floor the ornamentation of both will increase in value. The common use of carton, and the fact that in Paris there are firms of decorators who possess in their workshops models of nearly every form of enrichment invented since the sixteenth century, renders it possible to impart to any set of rooms any fashion of architectural ornament. These applied ornaments of *carton pierre* are of a more delicate description than can be obtained in London; and celebrated decorators like the MM. Huber Brothers, are hardly known in this country; yet some of the best buildings in France, and other parts of Europe, have been carved and ornamented by them. French woodwork is often overloaded with what when painted appears to be carving, but generally the enrichment is *carton pierre* stuck upon wood mouldings. In all flat residences mirrors are placed over the fireplaces, including those of the bedrooms; and they are neither fixtures nor furniture. The best French water-closet apparatus is scientifically made, and less complicated than many patented marvels in England; but the existence of a closed cesspool renders a copious flow of water impossible: hence much inconvenience. Since the time of Louis XV. this monument of human humiliation and relief has been called by Frenchmen "*l'anglaise*"—a compliment which Englishmen with habitual modesty are probably not unwilling to accept. A host of other things ought to be described, but time is relentless. Suffice it to point out sundry differences of custom in domestic life and its architecture between Paris and London.

The ordinary Paris house is built of stone, iron, and oak; the ordinary London one of brick and deal. The common house fronts of Paris are the works of architects; scrape a superior London residence and it is Gower Street disguised. The Parisian system of iron floors is fireproof; in London it is only those buildings technically called fireproof, of which when burning the firemen are afraid. In London the gas circulates in the walls between the joists, through cellars and roofs, in pipes embedded in plaster or cement; in Paris no gas-pipes can be legally concealed except they pass freely through an iron or zinc tube, having at each end direct communication with the open air. The Parisian uses his bedroom by day, and only eats in his dining-room; the Londoner often sits all day in his dining-room and only sleeps in his bed-room. The French use carpets which are always movable, those of the English are rarely raised; of the odors which sometimes emanate from houses in London many

are born of the carpet; those of a Parisian drawing-room savor of beeswax. The walls of the latter are painted; those of even a fashionable London house are papered. Bugs are of both nationalities, but the Parisian ones find little shelter in roofs, rafters and floor-joists forming a concrete mass of iron and plaster. The Parisians use thin walls of hollow bricks, the Londoners rack their brains over the philosophy of a trussed partition. A London kitchen and its offices occupy a whole floor, and represent the extreme of wastefulness; a Parisian kitchen covers a space of about 3 or 4 yards square, and is the extreme of economy. The Parisians early every morning deposit their dust at the side of the roadway; the Londoners carefully store theirs for days together beneath their own noses. French middle-class wives help their husbands in business; English wives of the same class often ignore office or shop. The Parisians cheat posterity, the Londoners ovorburden it. The Parisians live in Paris, the majority of Londoners live out of London.

To generalize, Paris lives in a flat, London in a house of its own.

THE CHANNEL TUNNEL.

By F. C. DANVERS, C. E.

From "Quarterly Journal of Science."

It is generally accepted as a geological fact that the high mountains and deep ravines that separate divers nations, and have been adopted by them as natural territorial boundaries, were developed, in some cases by gradual changes in the surface of the globe due to natural causes, whilst in others they are attributed, apparently with good reason, to violent convulsions of Nature, by the action of which the plane of the globe has been caused to undergo great changes. However these inequalities in the earth's surface may have been brought about, the necessities of man often demand that the inconveniences caused by them to free transit should be overcome, and to this end the services of the engineer are called into request—it may be to bridge over a river or chasm, to tunnel through a lofty mountain, under a river or across a channel of the sea. Further also the engineer may be called upon to unite two seas by means of a water communication, to divert the channel of a river, or to guard the coast against the errosive force of tidal action. Taking a general view of the engineering profession, it may be broadly stated that its chief and loftiest operations are undertaken with the view of accommodating the earth's surface to the need of mankind, either by counteracting the physicial effects of forces that were in operation in ages past, or by neutralizing present active forces by opposing to them means of resistance designed and based upon a knowledge of natural laws and physical science.

Many works of past ages may fairly claim to be classed in the general list given above, of which the most celebrated in modern times, at least, will readily present themselves to the mind of the reader. There is now, however, a grand work in contemplation, for uniting England and France by means of a railway tunnel under the English Channel, which in point of boldness of design and extensiveness—both from a material and commercial point of view—cannot claim a rival.

It is generally admitted by geologists that at one time England was connected with France by land, and formed a Peninsula. To all appearances also the separation from the Continent has not been effected by any violent convulsion, but by the slow and long-continued action of the waves. It was pointed out in an article that appeared in the "Quarterly Journal of Science" for April, 1872, on the "Geology of the Straits of Dover," that, very likely, at one time when the land stood at a higher level, and before the sea had eaten out

the Straits, a river ran from South to North through the chalk escarpment, which then stretched across from Folkestone to Wissant. The higher streams of this old river are the Rother on the English side, the Wimereux and the Slack on the French side.

The probability of this country having once been a peninsula, and of the land connecting it with the Continent being washed away by the action of the sea, was carefully considered by Verstigan, so long since as 1673, in a pamphlet dedicated to King James. He compared the identity of the strata, the composition of the cliffs, the similarity of their lengths, and arrived at the opinion that the surface had been gradually worn away by the action of the sea, and not by disruption. In the following century M. Desmarest wrote an essay on the same subject, arriving at the same conclusion ; and in 1818 the question was philosophically treated by Richard Phillips, F. R. S., in an elaborate essay which he read before the Geological Society.

Although, however, there appears to be little doubt that the Straits of Dover have thus been formed by the continued action of natural causes, it by no means follows that at no previous period had the even lay of the strata between England and France been disturbed by volcanic or other violent terrestrial forces. Between Folkestone and Cape Gris-Nez there is the Varne in mid-channel of a formation belonging to the Portland beds, which are of a much older series than the deposits to be found on either coast, and this of itself should prepare geologists to anticipate some irregular trend in the direction of the strata between the two shores. It may be that the irregularity is not of sufficient extent at the proposed line of passage materially to affect the projected work, but where an evident upheaval of the lower strata is known to occur within so short a distance of the selected site, it seems but reasonable to suppose that the effects of the disturbance by which it was caused may have influenced the geological formations within a few miles at least on either side of the fault. We shall, however, refer more particularly to this subject when treating of the geological examinations of the Channel bed.

It is not proposed in this article to enter into any detail regarding all the alternative schemes from time to time projected with the view of spanning more conveniently the narrow channel that now separates us from our neighbors, but it may render the present examination of the subject more interesting to refer briefly to the various devices proposed for obviating or lessening the inconveniences felt by those who suffer in crosssng between England and France from the too common complaint of *mal de mer*.

From M. Thome de Gamond's publication on this subject we learn that the establishment of some means of direct communication between England and France was first proposed at the latter end of the last century. The earliest project of which there is any account on record for crossing the Channel by a tunnel was proposed by M. Mathieu, a French mining engineer, in the service of the Department du Nord. His scheme was conceived at the close of the last century. It was laid before the First Consul in 1802, and plans illustrating the project were for several years exhibited, first at the Luxemburg Palace, then at the School of Mines, and afterwards at the Institute. Mathieu's project consisted of a subterranean way formed of two tunnels, one on the top of the other, forming in section an uneven line, the highest point being in the centre of the Channel, and inclining in opposite directions towards England and France respectively. The lower tunnel was to act as a canal to drain off any waters that might enter through leakage, and from which it would discharge at either end into drainage reservoirs. In the upper tunnel was formed a paved road, lighted by oil jets, and traversed by a service of diligences drawn by horses, which was the only known method of conveyance in those days. It is not shown exactly how the entrances to these tunnels were to be approached on either side, but they must necessarily have been situated at a great depth below the surface of the ground. For ventilating the tunnel, as well as for use in its construction, M. Mathieu proposed to erect circular iron chimneys rising above the surface of the water, and secured in position by masses of rock deposited at their bases.

When the Peace of Amiens was declared the author of this scheme thought that his project would be at once carried out. It was introduced to the notice of Fox on the occasion of his visit to Paris during the short peace that followed, and was received by him with favor: he regarded it as a most efficacious means of assuring peace between England and France. It is stated that Fox spoke on the subject to Napoleon, who exclaimed: "Oh ! c'est une des grandes choses que nous pourrous faire ensemble."

Subsequently, one Dr. Payerne proposed to form a level bed at the bottom of the sea by depositing concrete, and upon this to construct a tunnel by means of diving bells. MM. Franchot and Tessier proposed to form a passage through a tube of cast-iron laid on the bed of the sea, but they appear to have suggested no means for securing a level surface. M. Favre designed a submarine tunnel having an outside casing of wood or sheet iron, and resting on piers of iron lined with brickwork in order to overcome the unevenness of the sea bed. In 1850, M. Ernest Mayer proposed a submarine tunnel between the South Foreland and Cape Gris-Nez, and some years ago, M. S. Dunn laid out a plan for constructing a tunnel under the water, of which the principal novelty consisted in a cylindrical protector, fitted with a shield in front, within which the sections of the tunnel were to be fitted together.

The most indefatigable projectors amongst our neighbors has, however, been M. Thomé de Gamond. Whilst making a geological examination of the shores of the Channel in 1833, this engineer was first struck with the idea of making a way of communication between England and the Continent, and he accordingly proceeded to make a series of soundings between Calais and Dover. M. de Gamond's first project was for the submersion of an iron tube in sections, laid at the bottom of the Straits of Dover, and lined inside with masonry. The obstacle which soon presented itself to his mind was the difficulty of leveling the bottom of the sea in order to form a bed for the tube, and this operation alone he estimated at £12,000,000 sterling, after which the cost of the tube and approaches was set down at £6,400,000 ; so that the total probable cost of the project was £18,400,000. This scheme was no sooner finished than it was abandoned. In 1836, M. de Gamond gave his consideration to the construction of a bridge across the Channel, taking the line from Calais to Ness Corner Point, a line shorter by about two miles and a half than that between Dover and Calais. Five different plans of bridges, in granite, in stone and metal combined, and skeleton iron structures, were elaborated by him during a period of two years. The scaffolds for commencing the works were to be supported by buoys of great size, held in their place by metallic shrouds, fixed at the bottom of the sea to strong moorings. In making the foundations for the piers, it was proposed to drive piles into the ground by manual labor, the workmen being in a water-tight chamber at the bottom of the sea. Of all the different projects for this structure, the one for a granite bridge obtained most favor amongst scientific men. This structure was designed to be 131 yards broad, the arches, 162 yards wide, were to be built on piers 52 yards long and 131 yards broad. All the arches being 57 yards high above the sea could be passed under by most vessels. There was, however, to be one movable arch to admit the passage of vessels having still loftier masts. The greatest depth of sea between these points is stated to be 197 feet, and many of the arches crossing this depth would have been 126 yards in height from the sea-bed to the key-stone. The total cost of this structure was estimated by its designer at 160 millions sterling, but by others at 200 millions. At the advice of Messrs. Stephenson, Brunel and Locke, to whom all the plans were submitted in detail, this project was soon abandoned ; and in conversations which M. de Gamond had on the subject with those engineers—and especially with Mr. J. Locke—an idea was suggested of improving the means of communication between the two countries by narrowing the Straits of Dover, by throwing out piers from the two opposite shores, to be carried as far out to sea as possible, and establishing a steam communication between the two piers by means of an enormous raft moved by steam.

We defer for the present from entering further into detail regarding M.

Thomé de Gamond's more matured schemes for a Channel tunnel, whilst we refer briefly to other projects that have from time to time been put forward with the view of facilitating the Channel passage between England and France. Taking these in the order of their importance, we may perhaps devote a few lines first in considering plans that have from time to time been proposed with a view to counteract the motion of vessels in a rough sea, and so add to the convenience of travelers. The oldest invention of this sort, of which we have been able to trace any record, is mentioned in a curious old book, published in 1677, and named "Aero-Chanilos, or a Register for the Air." In it a sort of chamber is described, in which air might be rarefied or condensed, or otherwise changed for the use of invalids, so that they might have change of air without leaving home. Of this same chamber the writer says :—"Possibly, if the same might be made use of on board ship, it would (with the additional contrivance of a chair or bed, hung after the manner of a sea-compass) prevent that very troublesome affection whereto 'fresh men' are subject, called sea-sickness, and consequently become very serviceable to such whose emploiments engage them to undertake voyages into very remote parts, and there to reside far from their own countries."

The earliest patent on the subject appears to be that of Pratt (1826), in which a spring mattrass was fixed on a "swinging frame." A later invention by De Manara, in 1863, proposed to attach balloons to seats, in such a way as to keep them always horizontal. Another, by Ritchie, in 1866, describes a platform, resting on water in a tank, and having its edges attached to the edges of the tank by mackintosh, or similar fabric. Differing from all the above was a plan, patented in 1866, by M. Simpson, in which the body of the patient is firmly fastened down to the ship itself. In 1854, L. Wertheimher patented some improvements in apparatus for preventing sea-thickness, the first of which consists of a movable platform, to which chairs or couches may be attached. Connected with the platform is the piston rod of a steam cylinder, to which steam is admitted by a four-way cock, which may be opened and shut by a self-acting contrivance, so that when the ship sinks into the trough of the sea, steam is admitted beneath the piston, and the platform is caused to rise ; on the contrary, when the vessel rises over the crest of the wave, steam is admitted above the piston, and the platform descends, and thus a motion opposite to that of the vessel is obtained. Another arrangement consists of three cylinders, one placed forward and two at the after part, connected with each other by pipes. The second part of the invention consists of a platform or chair, which is supported by a bracket attached to an upright shaft, which shaft passes through a hollow standard. The upper part of the shaft carries a rack in which gears a pinion, fitted with an handle, and a rising and falling motion is given to the platform by moving the handle to and fro. Or the platform may be moved by a perpendicular shaft or lever attached to a pinion gearing with a toothed rack. In the third modification, the effect is attained by interposing elastic bodies between the person and the deck.

In order to avoid sea-sickness, Mr. J. Scarth, in 1869, designed a swinging cot, which he hung from four hooks—two at each end—whilst, in order to counteract the tendency to extreme oscillation, he attached vulcanized india-rubber springs, or accumulators, below the cot, in the exact centre, directly perpendicular from the hooks by which it was hung, and this principle he proposed to apply to individual berths. In 1833, Sir J. Herschel designed a somewhat similar contrivance, which, he says, proved perfectly successful, one chief difference between his and Mr. Scarth's plan being that instead of india-rubber bands Sir John employed cord or pack-thread. Subsequently, in 1869, Sir John Herschel proposed, for swinging cots, to transfer the whole coercing power, operative in deadening the effects of oscillation, at once to the point of suspension ; and so doing away with the necessity of attachment of any kind to the walls or floor of the cabin, whether by friction bands or by elastic straps, and this he proposed to accomplish by hanging the cot from the roof by a light but rigid iron framework, having a stiff ball-and-socket attachment lined with com-

pressed felt or other similar material, in order to offer sufficient frictional resistance to oscillation.

A floating cabin was designed by M. Alexandrovski, which, instead of being attached to a pivot, as in the Bessemer saloon, floated in a kind of tank placed amidships between the engines. This invention, it is said, was tested by the Grand Duke Constantine, in his capacity as head of the Naval Department, with a perfectly satisfactory result. All efforts to shake the cabin proving utterly unsuccessful, the pitching as well as the rolling motion of the vessel being completely counteracted. A combination of both the Bessemer and Alexandrovski plans was also recently proposed by Mr. A. Allen, of Scarborough, the object of which was to give a steady saloon cabin or gun deck at sea. This cabin was to be constructed of two spherical segments, the outer segment or dock being fixed in the ship, and the inner segment being floated on a film of water in the dock, like one basin floated in another, the inner one or cabin being maintained at its proper height by being supported on a centre pillar passing up a conical passage in its centre, and which would allow 20 degrees of roll on either side, or 40 degrees in all.

We have now to consider the several plans proposed for conveying trains across the Channel by huge ferry steamers. In the Exhibition of 1862, a proposition by Mr. Evan Leigh for conveying trains across the Straits of Dover on board large ferry boats or rafts was exhibited by means of models, but it does not appear that his project ever found any substantial supporters.

In 1865 a company was formed to place on the Channel a line of steamers from Dover to Calais, so large that the railway trains should run on board them, and there bodily remain to be run out again on the other side after crossing the Channel, and which, by their magnitude, it was expected, would ride over the waves without putting the passengers to the slightest inconvenience. The miseries hitherto inevitable to this passage had, it was remarked, been chiefly entailed by the restriction to boats of a size proportioned to the shallowness of the water on either shore. The new pier at Dover has overcome that objection on this side, and it was rumored that the French Government had granted a concession for the requisite extension of that at Calais on the other side. Such a scheme was indeed before Parliament in 1866, and was originated by Mr. J. Fowler, whose proposal was to construct steamers one-third longer than the vessels on the Kingstown and Holyhead service, and their decks were to be roofed over so as to protect the trains during the passage. The proposed dimensions of these vessels was—Length, 450 feet; breadth, 57 feet; with 12 feet draught of water. A Bill for effecting improved communication across the Channel by this means was three times before Parliament. In 1869 a project, having the support of Messrs. Fowler, Abernethy, and W. Wilson, contemplated the construction of very extensive harbor and dock works on either side of the Channel in addition to the construction of the large ferry steamers above referred to, and in November of that year an influential deputation from England laid the scheme before M. Gressier, the Minister of Public Works in France, by whom it was favorably entertained.

In consequence of the very defective state of the accommodation afforded by the Channel steamers plying between this country and the Continent, the Council of the Society of Arts, in 1869, offered the Gold Medal of the Society and the large Silver Medal of the Society for the best and the second best model of a steamer which would afford the most convenient shelter and accommodation to passengers on the deck of the vessel crossing the Channel between England and France. The size of the vessel was not to exceed in tonnage and draught the best vessel then in use between Folkestone and Boulogne. Seventeen models were sent in competition, which were referred to a Committee consisting of Lord Henry G. Lennox, M. P., Seymour Teulon, Rear-Admiral Ommanney, C. B., F. R. S., Admiral Ryder, E. J. Reed, C. B., Capt. Boxer, R. N., C. W. Merrifield, F. R. S., H. Cole, C. B., and Captain Tyler. From the report of this Committee it appears that three of the models only conformed to the conditions laid down by the Council, but none of these, in the opinion

of the Committee, presented sufficient novelty or merit to justify the award of the medal.

In this year also Captain Tyler, R. E., in compliance with instructions from the Board of Trade, visited the French and English coasts with a view to preliminary inquiry as to the improvements which might be effected in the means of communication between the two countries. He reported that considering the restrictions as to dimensions imposed by the circumstances of the harbors and the various conditions of the service, the steamers employed in the Channel service were admirably constructed for the work they were required to perform. With regard to Mr. Fowler's proposal for large steamers and improved harbor accommodation on both sides of the Channel, Captain Tyler observed that it was a question whether it would be worth while to ferry the railway carriages as well as the passengers across the Channel; but that the main features of an improved harbor at Dover and a new harbor south of Cape Gris-Nez were sound, if means could be found for meeting so great an expense as the works would entail. Captain Tyler then proceeded to consider the practicability of improving the existing harbors so as to fit them for a service of larger vessels, after which he directed attention to the bolder schemes which had been put forward from time to time for avoiding the use of steam vessels altogether by the construction of bridges, or tunnels, or tubes over, under, or in the bed of the Channel, with or without islands, piers, or air-shaft, so as to connect the railway system of England directly with that of the Continent.

After briefly referring to the plan proposed by M. Mathieu, Captain Tyler proceeded to observe that, after a series of geological investigations, M. Thomé de Gamond also proposed, in 1856, the construction of a tunnel, and his propositions were submitted to the examination of a scientific Committee by order of the French Emperor in that year. That commission appears to have come to the conclusion that it was desirable to test his investigations by sinking shafts and driving short headings under the sea at the expense of the two Governments. Mr. Low, an English engineer, also laid his plans for a tunnel before the Emperor in 1867, and Mr. Hawkshaw, whose attention had been for some years directed to the subject, caused a trial boring to be sunk on each side of the Channel in 1866, in order to test practically the result of his geological investigations. Mr. Remington published a plan for a tunnel in 1865, and deposited plans and sections of it with the Board of Trade. And amongst the names of other proposers or projectors in this direction may be enumerated Messrs. Franchot, Tessier, Favre, Mayer, Dunn, Austin, Sankey, Boutet, Hawkins Simpson, Boyd and Chalmers. Of these various projects those which have of late made the most progress are the bridge scheme of M. Boutet, and the tunnel scheme presented under the chairmanship of Lord Richard Grosvenor, with Messrs. Hawkshaw, Brunlees and Low, as engineers on the English side, assisted by Messrs. Talabot, Michel Chevalier, and Thomé de Gamond, on the French side. The result of the deliberations of a French commission, which was appointed by the Emperor, and presided over by M. Combes, the Director-General of the Ecole des Mines, to inquire into this last-mentioned scheme, were on the whole favorable as regards the geological and engineering parts of the project, though the members of the commission were divided as regards its financial prospects, the president and two members attaching more importance to the "utility and grandeur of the undertaking," and three other members looking at it from a more strictly economical point of view. The General Council of Pont-et-Chaussées, presided over by the Minister of Public Works, to whom the matter was afterwards referred, were unable, "upon the documents submitted to them, to decide on the probability of success of the tunnel under the Channel," and considered that "if from political considerations, the undertaking should be considered useful, the Government should follow up the investigations at their own expense."

In reporting on the different projects put forward with a view to improving the means of communication between England and France, Captain Tyler, referring to the last mentioned project, remarked :

"In this scheme it is proposed to com-

mence by driving preliminary driftways through the gray chalk, at a great depth below the bed of the Channel, between a point near Dover and another point near Calais; as it is conceived that this material would be easily cut through, and would not be likely to present insuperable difficulties from the influx of water; whereas Mr. Remington selects the line from Dungeness to Cape Gris-Nez, in order to avoid the chalk, and the fissures which he fears to encounter in it, and to work in the Wealden formation, which would, he believes, afford a greater chance of success.

"In the case of M. Boutet's bridge scheme, an association has been formed for making experiments, two small bridges have been built in France, and arrangements are made near St. Malo for a third, a mile in length, to be constructed in two spans of half a mile each. The Emperor Napoleon visited the works of M. Boutet, on a site granted by the French Government, and His Majesty is stated to have expressed himself favorably with regard to the project. This bridge is intended to cross from Dover to Blancnez, and is advocated, in a paper forwarded on the 27th June to the Board of Trade as (1) being less costly than a tunnel; (2) occupying less time in construction; (3) giving no trouble in ventilation; (4) avoiding the danger of sudden inundations.

"Mr. Charles Boyd has forwarded to the Board of Trade a pamphlet containing his proposal for a 'marine viaduct' from Dover to Cape Gris-Nez, constructed with iron girders on 190 towers, 500 feet apart, and 500 feet above the sea, and he estimates the cost of such a bridge at £30,000,000.

"Mr. Hawkins Simpson has addressed the Board of Trade on the subject of working a submarine tunnel on a pneumatic system, which he has termed his 'Eolian system,' for which he claims cheapness, expedition, superior ventilation and greater utility.

"Mr. Alexander Vacherot has submitted to the Board of Trade a scheme on which he has several years been engaged, and which he laid before the Emperor of the French in 1856, for 'laying on the bed of the sea a tunnel made or formed of concrete, so as to form, when completed, a monolith.' He would construct it on the shore and 'draw it down to its place in sections.' And he considers that greater economy and security might thus be obtained than by the other methods that have been proposed."

After reviewing these several projects Captain Tyler, though unable to convince himself of the feasability of any bridge scheme, considered "that it might be wise to test the practicability of a tunnel scheme by means of preliminary driftways. It is probable," he said, "that, even if any of them should hereafter be carried out in practice, they could not go forward otherwise than under the supervision of, and a previous guarantee from, the two Governments; and obvious that, as at least 10 or perhaps 15 years may elapse before they could be made available for traffic, improvements in the shape of more convenient and larger steam vessels are required in the meantime for the better performance of the service."

In the spring of 1870, Vice-Admiral Sir Edward Belcher read a paper before the Institution of Naval Architects, wherein he expressed himself favorable to a proposed ferry scheme, and to the practicability of constructing ferry steamers suitable for the service. The outbreak of war on the Continent put an end to Mr. Fowler's project; but, in 1871, we find M. Dupuy de Lôme at the head of a similar undertaking in France. His project was for, first, the creation at Calais of a maritime station, with 16 feet 6 inches depth of water at the lowest tides, and about 30 acres in area, connected with the shore by an iron railway jetty, making a junction with a branch of the Northern Railway—and open to the sea by an entrance 260 feet wide, accessible in all weathers, and at every stage of the tide; secondly, the construction, for crossing the Channel, of steam vessels of large dimensions and of great power, embracing all of the most important conditions of speed and comfort, and able to carry 30 passenger carriages or goods wagons. These vehicles would be placed on a double line of rails running fore and aft; they would be shipped and unshipped by the assistance of a system of inclined planes leading to three landing stages of different heights, and alongside which the ferries would run according to the state of the

tide. A paper on this subject was read by M. Dupuy de Lôme, before the French Geological Society, in 1873. In 1871, the Society of Arts appointed a Committee to consider and report how far the existing means of crossing the Channel could be improved. In their report several modifications in existing vessels, and new boats about fifty feet longer than the existing boats, were suggested, but an opinion was expressed that no large measure of improvement could be effected in the Channel passage unless with vessels of much larger size, which would involve, in the first instance, considerable improvements in the French harbors of Calais and Boulogne, and subsequently the extension of the low-water pier at Folkestone.

Mr. Fowler again brought forward his ferry scheme in 1872, and Mr. Hawkshaw at the same time was supporting an alternative design for an improvement of the existing means of communication by the establishment of a service of vessels of considerable size, to which the existing harbors might be adapted without an excessive cost.

The bill for Mr. Fowler's project passed the House of Commons in 1872, but it was thrown out in the Lords by a very small majority. From this date comprehensive schemes for a railway ferry across the Channel appear to have been abandoned, and in their place projects were started, the one by Mr. Dicey and the other by Mr. Bessemer, for constructing steamers of special and novel design, on board of which passengers would be enabled to undertake the passage across the Channel without fear, no matter how bad sailors they might be. Both of these vessels have now been constructed, and as they have been described in former pages of this journal, it is not necessary to enter into any detailed description of them on the present occasion.

Having now made a rapid review of the general question of improved communication between England and Europe, and of the several projects that have from time to time been proposed for the purpose, it remains only to enter somewhat more fully into detail with regard to the great tunnel scheme which, to all present appearances, is about to be commenced. In doing this, we shall purposely avoid all reference to the probable traffic and commercial results of the undertaking, and shall confine our investigations to the proposed line of route, the geological features of the strata to be pierced, and the general engineering features of the work.

Two principal schemes have been proposed for a tunnel under the Channel, the one by M. Thomé de Gamond between Eastwear Bay near Folkestone, on the English side, to Cape Gris-Nez on the French coast, and the other, which has already been referred to, and with which the names of Hawkshaw, Brunless, and Low are associated, from between St. Margaret's Bay, near the South Foreland, to a point between Sangatte and Calais. The former of these, it was subsequently ascertained, would pass through a number of different beds. In mid-channel on this line there are two shoals, known as the Varne and the Ridge, which belong to the Portland formation, the same as that to which the cliffs at Cape Gris-Nez belong, and under it are the Kimmeridge Beds. These rocks dip to the north-west, and it is supposed that somewhere between Cape Gris-Nez and the Varne the Kimmeridge clay wholly disappears, whilst somewhere to the west of the Varne and nearer to the English coast the Portland beds also disappear and are overlaid by the Wealden series. Probably the Hastings beds immediately overlie these, and above them again is the Weald clay ; but where the outcrop occurs, or what is the thickness of the various beds, is not known. M. de Gamond's tunnel, therefore, as was pointed out by Mr. William Topley in an article on the "Geology of the Straits of Dover," would pass through a number of different beds ; but how many is uncertain, for it crosses the lines along which the changes above indicated must somewhere occur. There is no doubt that it would pass through all the English divisions of the Lower Greensand, for it would intersect these very near the coast ; and it cannot be supposed that the change which these must undergo takes place suddenly. Farther out in the Channel it would probably go through Weald clay, possibly it might touch the Hastings beds ; beyond this again it might intersect the Portland, and finally it would cut through the

Kimmeridge. The various beds that would be intersected by this tunnel are of very different characters ; some are highly porous and some wholly impervious.

The tunnel which it is proposed to take from St. Margaret's Bay to near Sangatte will, it is supposed, go entirely through the chalk without flints. The following particulars of this project are taken from a paper on the "Channel Tunnel" read before the Society of Arts on the 18th March, 1874, by Mr. W. Hawes, F. G. S., and from a "Statement by the Committee of the Channel Tunnel Company (Limited)" published in 1874.

In 1865 Sir John Hawkshaw began his practical researches into the nature of the strata beneath the Channel, which confirmed the theories of the geologists, threw new light on the subject, and put the question of a submarine tunnel in a position to be seriously discussed and considered by the public. Before that time he had given the subject much consideration, but in that year he caused careful geological surveys and investigations to be made of the Channel, and afterwards, in conjunction with the late Mr. Brassey and Mr. George Wythes, had borings sunk on each coast. Subsequently, by means of apparatus contrived for the purpose, he examined the bottom of the channel all across in a great number of places, and raised specimens of the sea bed for examination, by which it appears to have been satisfactorily established that the actual position of the chalk across the Channel is very nearly identical with that deduced from previous inquiries, and its unbroken continuity placed almost beyond doubt. Its thickness, determined by deep borings on both sides, is proved to be above 500 feet below high-water mark, with an ample thickness of the lower or gray chalk between the bottom of the sea—which is nowhere more than 180 feet deep—and the crown of the tunnel, as well as between the bottom of the tunnel and the green sand or water-bearing strata underlying the gray chalk. The tunnel has been placed by the engineers at such a level that the depth of strata over it will nowhere be less than 200 feet, and this depth, which is desirable for security, will permit the railway approaches to be formed with not unfavorable gradients.

In the opinion of M. de Souch, Inspector-General of Mines in France, the lines selected by the engineers of the Channel Tunnel Company is the only one which presents chances of success, and is the only rational one. The Commission appointed by the late Emperor of the French to examine this project reported that there was every reason to believe that the chalk formation extends under the Channel between Dover and Calais, and that "the thickness of the gray chalk gives a certain latitude for the maintenance of the tunnel in the same direction, even where the level of the bed of the sea may be subject to some undulations ; and they believe that the existence of any great fracture in the chalk is very improbable."

On the other hand, we have the opinion of so high an authority as Mr. Joseph Prestwich, Vice-President of the Geological Society, who does not entertain such sanguine views as to the suitability of the chalk stratum for the construction of the proposed tunnel, as will be seen from the following remarks extracted from a paper read by him before the Institution of Civil Engineers in December, 1873 :

"The chalk formation, which everywhere in the south-east of England and the north-west of France underlies the Tertiary series, has a maximum thickness of from 1,000 feet to 1,300 feet; but, as much of it has in this area been worn away or denuded before the deposition of the Tertiary strata, its actual thickness in the district under notice varies from 300 or 400 feet to 800 or 1,000 feet. The upper beds consist of almost pure carbonate of lime, easily worn by water, and being also soft and fissured they are readily permeable. But the Lower Chalk or Chalk Marl contains so large a proportion of argillaceous matter and silica in a state of fine division that some beds pass almost into a clay, and when unbroken and compact very little water can pass through them, and then only with extreme slowness, though this will increase under pressure. But although a small bore-hole or even a shaft may often be carried through a considerable thickness of Lower Chalk and no water obtained, the occurrence of fissures is

too uncertain to render it a reliable medium over a large area. In some cases where the Lower Chalk comes to the surface, and is more broken and fissured, the quantity of water it yields is very large, as in the instance of the Tring cutting described by Robert Stephenson, where the discharge was at the rate of 1,000,000 gallons per day ; or at Folkestone, where the town water supply is obtained from the Lower Chalk of the adjacent downs. On the other hand, the Chalk Marl in France and Belgium acts as an impermeable stratum in stopping the passage of water from the very permeable Upper Chalk into the underlying coal measures ; and no water was found in it either at Kentish Town, Harwich, Southampton, or Calais ; but the diameter of the bore-holes by which they were traversed were very small. At Calais one spring was met with at a depth of 70 feet in the Upper Chalk, and the water was brackish, showing communication with the sea. Nor must it be forgotten that wells in the Chalk under London have to be carried or bored to depths of from 10 to 300 feet before meeting with water-bearing fissures, or else headings have to be driven in search of one. Again, the escarpment of the North Downs and that of the chalk hills of Wiltshire, Oxfordshire, and Buckinghamshire, are fringed with numerous springs, which issue at their base. These springs, although thrown out generally by the Chalk Marl, are apparently not always at the top of it, but often low down in the deposit, and they constantly wear their point of issue from a higher to a lower level. Whatever the level of the spring the water of course passes through all the superincumbent portions of the Chalk Marl. This very commonly impermeable character of the Chalk Marl has given rise to the hope that it might prove compact enough for a submarine tunnel under the Channel between Cape Blancnez and the South Foreland ; but when it is considered that such a work would have to face the risks arising from the lateral passage of the inland springs and from the chance fissures so common to calcareous rocks communicating with the sea, it is feared that the difficulties would prove to be of a very formidable nature. It is to be observed that in the Channel the chalk is frequently bare, besides being unprotected by any overlying strata."

The foregoing observations demand our full respect, but, on the other hand, the possibility of tunneling beneath the sea without being exposed to an irruption of sea water is shown in the submarine galleries of some mines in Cornwall, Cumberland and elsewhere. In a treatise on Mines and Mining by Mr. Price, published in 1778, he treats especially of mining under the sea, and refers particularly to the freedom of water in such works.

It is probable, and the engineers anticpate that at the shore end of the Channel Tunnel, especially in constructing the shaft through the upper strata, a considerable quantity of water will be met with, but not sufficient to prevent the execution of the work, where pumping power of any magnitude could, if necessary, be applied. It is believed, and there appear to be reasonable grounds for such belief, that as the work attains a greater depth in the chalk, and especially after the lower or gray chalk is reached, the quantity of water will diminish, and that in mid-channel it will be less than at the sides.

The geological features of this project having now been duly considered, it remains to give some particulars of the engineering nature of the work. The distance across the Channel at the point selected is about 22 miles, but as considerable approaches will be necessary on either shore, in order to reach the level of the tunnel entrance, the entire scheme will embrace about 31 miles of railway. In the first instance shafts will be sunk on each shore to the depth of 450 feet below high-water mark, and, from the bottom of these, driftways will be driven for the drainage of the works whilst in progress, and for its permanent drainage after completion. The tunnel, which will be very similar to an ordinary railway tunnel having two lines of rails, will commence 200 feet above this driftway, and will be driven at an inclination of one foot in 80 to the junction with the drainage driftway, and then at a gradient of one to 2,640 to the centre of the Straits, where the tunnel from the English shore will meet that driven exactly in the same manner from the French shore, and, being united with it,

will complete the submarine railway under the Channel. The drainage will be from the centre of the tunnel to either end.

In the execution of this work a driftway, 9 feet in diameter, will first be carried right through, and this will afterwards be enlarged to the full size of the tunnel. The problem of the execution of the tunnel in a reasonable time has been simplified by the invention of tunneling machinery, and the machine of Mr. Dickenson Brunton, which has been tried on a practical scale by the company in the lower or gray chalk, has been quite successful. The machine works like an augur boring a hole in wood. The chalk is cut off in slices, which break up and fall upon an endless band, which loads them into wagons behind the machine. The apparatus was tried by the Company at Messrs. Lee's Cement Works, Snodland, near Rochester, in the gray or lower bed of chalk, such as underlies the Channel. It made a driftway of 7 feet diameter, and it advanced at the rate of from a yard to a yard and a quarter per hour. At this rate it would only require two years to drive a driftway of 7 or 9 feet diameter from one side of the Channel to the other, a machine being started from each side. The cost of driving a heading would consist—1st, of tunneling machines, pumps, and pumping engines; 2nd, the hand labor, which would not be considerable, as the machine requires but few hands to work it; and, 3rd, interest on the capital expended during the execution of the work, which might last two years or more. Taking these three elements of expenditure into consideration and according to the calculations of experienced contractors, it has been found that the driftway could be executed for £800,000, if it required only two years to make it.

As soon as the driftway was completed the success of the undertaking would be assured. It would furnish the necessary data for an exact estimation of the cost of the whole work and the time necessary for its execution. In fact, all that would be necessary would be to enlarge the driftway to the dimensions of an ordinary railway tunnel. It has been estimated by some engineers and contractors of considerable experience that after the driftway was finished, four years' time and four millions of money would complete the work, including the junctions with the English and French railways on either shore. Sir John Hawkshaw and the engineers associated with him, however, think it prudent to double this estimate both of time and of cost, at least until the preliminary work shall have given them the necessary data for a more exact estimate of the duration and cost of the work.

Preliminary steps to test the practicability of the project are about to be put in hand without further delay, for which purpose an English and a French Company have been promoted to carry out experimental works on either side of the Channel. An Act has been passed by the British Parliament during the past Session to enable the English Company to acquire the necessary lands at St. Margaret's Bay, and it is understood that a *projet du loi* has also been passed in the French Senate to confer the necessary powers on the French Company. The works to be undertaken by these companies consist of sinking two shafts—one on either coast—about 150 yards deep, from which an ordinary mining drifting about half a mile long will be driven under the sea. This work would be a true beginning of the proposed permanent tunnel. Its cost is estimated at £160,000, of which sum it is understood the two companies will find £20,000 each; the Rothschilds of London and Paris have each undertaken to find similar amounts; the Chemin de Fer du Nord will contribute £40,000, and the London, Chatham, and Dover and South-Eastern Railways will respectively subscribe £20,000.

It may now be confidently anticipated that the commencement of this great work will not be delayed. In the foregoing account we have purposely refrained from entering into detail regarding means of ventilation and other minutiæ of construction. The progress of the work will, however, be closely watched, and we shall hope from time to time to give further particulars of its advancement in the chronicles of engineering in this journal.

TEST OF HOWARD BOILERS AT THE FAIR OF THE AMERICAN INSTITUTE.

BY THERON SKEEL.

II.

A given amount of heat being developed for each lb. of fuel consumed in the furnace it is evident that one kind of boiler may be made as economical as another by simply giving to it a sufficient amount of heating surface to reduce the products of combustion when delivered into the chimney to the same temperature.

It may however be that a certain arrangement and proportion of heating and grate surface will effect the reduction of the products of combustion to the required temperature more readily than another.

The boiler then which will produce this result for the least original cost, offering the same time the best facility for inspection and repairs, occupying the least space and being equally safe and durable, is undoubtedly the best boiler.

Generally, however, no one boiler excels in all these qualities at the same time, and the purchaser must decide how much weight he will allow to each one in selecting the *best boiler for his purpose.*

The Committee on steam boilers, on the exhibition of 1871, allowed each of the first four of these qualities equal weight. The following are their marks to a scale of 10 :*

	Safety.	Dur.	Econ.	Cap.	Mean.
Root A..............	9	9	7.09	7.3	8 098
Allen B..............	8.5	8.5	7.07	10	8.196
Phleger C..............	7.	6	6.99	7.7	6.672
Low D..............	5.5	5.5	6.93	8.1	5.760
Blanchard E..............	6.	5	7.56	5.6	6.040

It will be observed that they omitted the item of first cost entirely, preferring to leave that to the judgment of the purchaser.

It is not a fair comparison to allow the boiler to enter the above table at different rates of combustion, for any boiler may considerably increase its rate of combustion without proportionally decreasing its economy, and it is apparent that the boiler which has the highest rate of combustion has in such a comparison the advantage.

In order that the results shall be fairly comparable, each boiler should be consuming coal at exactly the same rate during the experiments. As it is impracticable to have these conditions it is necessary to reduce them to the same rate. In doing this, they may be rated either by their heating surface or their grate surface. It appears that for this *class* of boilers, the heating surface being the measure of the first cost, should be the unit of comparison. After reducing the economy and capacity from those found in the experiment, to those that would obtain at a given rate of combustion per square foot of heating surface, the results are fairly comparable.

This method can only be assumed when there is no difficulty in burning on the grate furnished the necessary amount of coal.

The following reduction is made by the formulæ given by Prof. Rankine, on the supposition that each boiler shall burn ½ lb. of combustible per hour per square foot of heating surface. The *lbs.* of combustible per square foot per hour will be :

* Rep. Committee on Steam Boilers, Am. Inst. Fair, 1871.

Root	A	$16\frac{1}{4}$
Allen	B	$14\frac{1}{4}$
Phleger	C	13
Low	D	12.1
Blanchard	E	20.9

In reducing the economy from the experiment the ratio of all heating surface to the grate surface is used.

The following will be the economy :

Root	A	.670
Allen	B	.696
Phleger	C	.649
Low	D	.642
Blanchard	E	.646

As these boilers are all supposed to be burning coal at the same rate, their capacities will be in the same ratio as their economies, and the final results will be :

		Safety.	Dur.	Cap.	Econ.	Mean.
Root	A	9	9	6.70	6.70	7.85
Allen	B	8.5	8.5	6.96	6.96	7.73
Phleger	C	7.	6.	6.49	6.49	6.50
Low	D	5 5	5.5	6.42	6.42	5.96
Blanchard	E	6.	5.	6.46	6.46	5.98

It will be observed that the rate of combustion is not more than could have been obtained with good chimney draft in any case except (E).

The superiority of the (B) over the (A) in economy was undoubtedly owing to the feed water heater in the chimney, being 30 □′ of tube surface, for although there was in the experiment 40 per cent. less proportion of heating surface to coal consumed, the temperature of the gases leaving the boiler was 71° less in the "B" than in the "A" corresponding to about 3 per cent. The A had no feed water heater.

A boiler of the proportions used in the case of the (D), with the ordinary arrangement of furnace, should have given an efficiency of about 75 per cent. at the rate of combustion in the table.*

The loss of efficiency (75—64=) 11 per cent. was probably due to the admission of cold air into the combustion chamber through an opening designed for that purpose.† For it has been experimentally proved that such an admission is detrimental.‡ It will be observed that the high economy of the (C) boiler at the low rate of combustion at which it was tried, disappears when it is reduced to a rate of combustion corresponding to its heating surface. This is to be expected, for the draught was in that case forced by a blower, and the steam used deducted from the evaporation of the boiler.

Thus this boiler expended a certain amount of steam to obtain the draught which the others got free of cost from the small specific gravity of the products of combustion in the smoke stack, due to the high temperature at which they were necessarily rejected ; it must be noted that the temperature in the flue of the (C) boiler would become much higher at the higher rate of combustion.

The total weight of coal fed into the furnace of the Howard Boiler, during the experiment, was 5,100 lbs., and the weight of ashes and coal drawn out was 1,158 lbs., and therefore the combustible consumed was 3,942 lbs. The duration of the experiment was $21\frac{1}{2}$ hours, and therefore the lbs. of combustible consumed per hour were (3942 ÷21.5=) 183.5, and the lbs. of combustible per square foot per hour were (183.5÷27=) 6.8. The amount of refuse withdrawn from the furnace is not a measure of the amount of refuse in the coal, as a large part of the matter withdrawn was coal which might have been consumed if the experiment had continued longer, and if the refuse had been picked.

If the proportion of refuse in the coal

* Report of Board on Vertical and Horizontal Tube Boilers. 1868.

† Report of Board on Trial of Steam Boiler, Am. Inst. Fair, 1871.

‡ Ex. Res. in Steam Engineering, Vol. II., p. 58, Vol. I., p. 275.

were one-sixth of its weight, an average amount for anthracite coal, the total weight of *coal consumed* would have been $(3942+3942\div5=)$ 4730; and the weight of coal per hour $(4730\div21.5)$220; and the lbs. of coal per hour per square foot $=(220\div27=)$ 8.15. This is a very low rate of combustion. In ordinary practice, such a boiler should have given a rate of from 18 to 22 lbs. of coal per square foot per hour, where the fires were urged as in this case.

The cause of the slow combustion was undoubtedly a leakage of air into the chimney through the boiler casing.

This cold air acted to reduce the combustion in two ways:

1st. By reducing the temperature of the air in the chimney, and thus reducing the velocity of the ascending current, and the volume of air delivered.

2d. By supplying a portion of the air delivered by the chimney from the outside, and thus still further reducing the amount which must pass through the fire.

The effect of the reduction of temperature on the draught is small, for while the velocity of the ascending current is *reduced* its density is *increased.* The effect of these two simultaneous changes nearly balance, although there is a gradual increase of the weight of air developed up to about 600°.

The ratio of the weight of air, which was delivered by the chimney to that which would have been delivered if the temperature of the air in the chimney had been the same as that leaving the boiler, *i. e.* 328° may be completed from the formulæ applicable to be as 100:108.*

Thus, if the air in the flue had not been diluted after leaving the boiler, but had had in the chimney a temperatare of 328° in place of 234°.5, the furnace would have consumed $(183.5\times1.08=)$ 198.2 lbs. of combustible per hour, being $(198.2\div27=)$ 7.3 lbs. per square foot.

The temperature of the gas in the chimney was reduced after leaving the boiler by the addition of a certain quantity of air which leaked in through boiler No. 4, and past the dividing wall as before described. The portion of air at

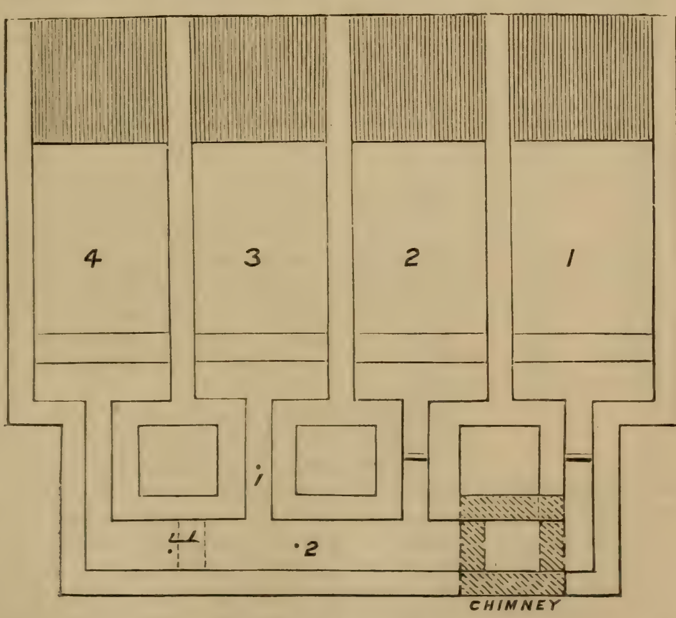


FIG. No. 4.

a temperature of 45°, which would by mixing with a unit of gas at 328° give a resulting temperature of 234°.5, is found to be $\left(100\times\frac{328-230}{230-45}=\right)$ 53 per cent. Of all the gas passing up the

* Steam Engine and other Prime Movers. Rankine, p. 288. Ed. 1866.

chimney then $(100 \times 53 \div 153 =)$ 65.4 per cent. passed through the No. 3. If the leakage of air through Boiler No. 4 had been stopped, the same head of gas in the chimney would have drawn more air through the coal in the ratio $[100 : \sqrt{(100)^2+(53)^2}=]$ 113.5, and therefore the rate of combustion would have been $(198.2 \times 113.5 =)$ 225 lbs. combustible per hour, and $(225 \div 27 =)$ 8.3 lbs. of combustible, or $\left(8.3+\frac{8.3}{5}=\right)$ 10 lbs. coal per square foot of grate per hour.

The combustion was also reduced by choking of the connecting flue between the boiler, No. 3, and the main flue by the sand pot and bricks, as shown in Fig. No. 8.

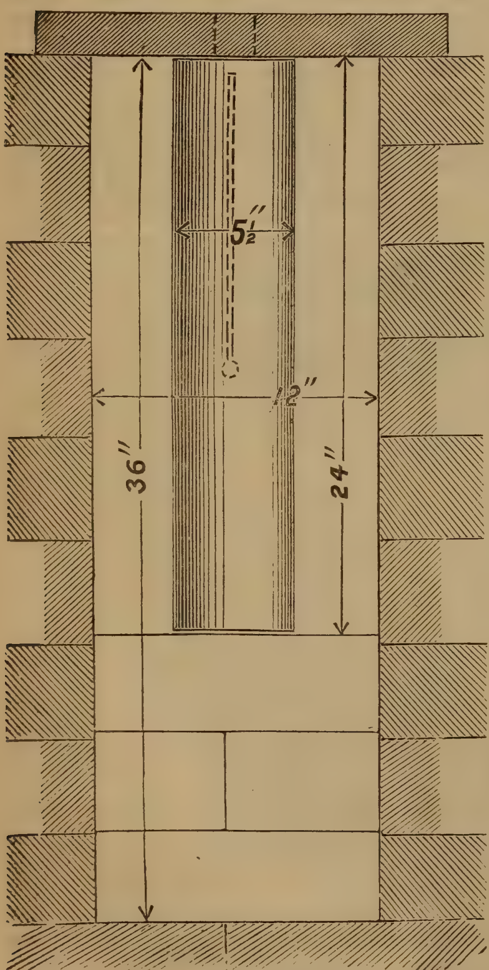


FIG. No. 8.

The original section was 3 square feet, being one-ninth of the grate surface, and the reduced section was $1\frac{1}{4}$ square feet, being 1 : 21.6 of grate surface.

It will be observed that there is another section, being the 1st connection of but little more than this, but as that was only reduced so small by a small excess of length of the iron plates laid upon the tubes, which could be easily remedied, it may be disregarded.

It appears from comparison of other boilers that for any cross sections of flue less than $\frac{1}{8}$ the grate, the amounts of coal that may be burned are in the ratio of the square roots of the ratio of the sections. Thus, if the section of the flue had been $\frac{1}{9}$ of the grate in place of $\frac{1}{21.6}$, there would have been more coal consumed in the ratio $(\sqrt{21.6 \div 9}=)1.55 : 1$, whence the consumption of combustible per hour would have been $(225 \times 1.55 =)$ 310 lbs., and the lbs. per square foot of grate per hour=11.5 lbs., and the lbs. of coal per square ft. per hour $(11.5 \times 1.2 =)$ 13.8. Therefore, the most rapid combustion possible in the boiler, as built if it had been connected to the chimney independent of the other boilers, would have been $13\frac{8}{10}$ lbs. of coal per hour. The economy would have been* at this rate of combustion $9\frac{56}{100}$ lbs. of water from 212° per lb. of combustible, and the capacity 2,964 lbs. of steam per hour from 212° temperature of feed water.

It is believed that the rate of combustion was injured by the air which leaked into the combustion chamber through the false front to the boiler. This front was formed of cast iron plates not planed, and only held loosely together by lugs cast on them. The plates exposed a joint 70 feet long in the aggregate. It has been found experimentally that air will flow under the pressure of the experiment, $\frac{15}{100}$ inches of water, at the rate of 18 feet per second.† Each square inch of opening would then deliver $\frac{1}{8}$ cubic feet per second. It has been found that 53 per cent. of the air passing from boiler No. 3 leaked in through the false front of boiler No. 4. If the same amount should have leaked in through

* Steam Engine and other Prime Movers. Rankine, Ed. 1866.

† Experiments on flow of air. Wilson Engineering, 1872.

boiler No. 3's false front, and there would appear to be no reason why this is not probable, only (100—53=) 47 per cent. of the air passing through the tubes passed through the fire. If this leakage through the false front should be stopped, the same head of gas in the chimney would consume more coal in the grate in the ratio of $\sqrt{100}:\sqrt{37}=100:61$, and the maximum combustion would be $(310\times100\div61=)$ 510 lbs. combustible per hour, being $18\frac{8}{10}$ lbs. combustible, or 22 lbs. of coal per square foot per hour.

It is believed that is the maximum for this boiler.

The quality of the coal is always a vexed question on comparison of experiments on boilers. It is believed that this may be computed with a sufficient degree of accuracy from the measurements recorded in this experiment.

The weight of water evaporated, and that entrained with the steam measure, the amount of heat passing through the metal of the boiler into the water. The weight of gas passing up the chimney with its elevation of temperature measures the amount of heat passing up the flue.

If there is added to these the heat lost by radiation, and that remaining undeveloped in the gas owing to incomplete combustion, we have the total heat contained in the material consumed. The method of measuring the water evaporated and entrained, has been explained.

The volume of gas passing up the chimney was computed by multiplying its velocity by the mean area of the flue. The velocity was measured as follows:

A small hole one inch in diameter was drilled through the side of the chimney, 50 feet down from the top. A small piece of cotton wool was placed in this hole, where it laid held by the friction of the walls. An observer was stationed at a point in the yard, from which both the top of the chimney and the opening through the side were visible. At a given signal, the wool was crowded through the side of the chimney with an iron rod. The observer in the yard noted the interval between the times when he saw the wool crowded through the side of the chimney and when it appeared at the top.

The mean of twelve experiments gave an interval of 8 seconds, whence the velocity of the wool upward in the flue was $\frac{50}{8}=6.25$ feet per second. The velocity of specimens of the same material was afterwards found to be, when falling in still air, 5.15 feet per second, and therefore the velocity of the gas in the flue was $(5.15 + 6.25 =)$ 11.4 feet per second.

A part of the chimney, for 30 feet above the opening, had an area of 4.0 square feet and the balance, the upper 20 feet, an area of 4.9 square feet, whence the mean area was $(4\times30+4.9\times20)\div50=4.36\,\square'$, and the volume of gas delivered was, per hour $(4.36\times11.4\times3600=)$ 178920 cubic feet.

The weight of a cubic foot of air at a temperature of 234.6, the mean temperature of the chimney, was .0572 lbs., whence the weight of air passing up the chimney in lbs. is$(178920\times.0572=)$10234 per hour. In addition to this amount of air, there were 183.5 lbs. of combustible matter from the coal also passing up the chimney per hour, making the weight of gas $(10234 + 183.5 =)$ 10417.5. This weight of gas was raised from a temperature of 35° to 235°, and if its specific heat were $\frac{.24}{100}$, the units of heat carried away by the gas would be per hour $10417.5\times200\times.24=500016$, and for each lb. of combustible $(500016 \div 183.5=)$ 2724. The heat equivalent to the steam produced by one lb. of combustible is $(10.53\times966=)$ 10171, and equivalent to the water entrained is $(.823\times294°=)$ 242. The portion of the heat dissipated in the three ways mentioned then is for each lb. of combustible:

Steam	10171
Water.................	242
Gas	2724
	13137

There must be added to this the heat dissipated by radiation, and that not developed by combustion.

The heat lost by radiation was probably small, but the Committee have no means of estimating it. It was, however, not sufficient to sensibly elevate the temperature of the fire-room, the room being during the day time colder than the outside air. The heat lost by incomplete combustion may be taken at,

at least six per cent., as has been found in similar boilers and rates of combustion when the *holes in the furnace door were closed*,* whence the thermal equivalent becomes ($13137 \times 106 =$) 13925 units of heat.

Probably the thermal equivalent of this coal may be taken to be 14,000 units of heat per lb. of combustible, the combustible being understood to be the material of any kind whatever which disappears in the furnace. One pound of combustible will be capable of evaporating $14\frac{1}{2}$ lbs. of water at and from 212°.

One probable reason why the combustible matter showed less heating powers than the average coal is that only a portion, and that the least efficient portion, of the combustible in the coal was consumed.

Thus, there was supplied to the furnace 5,100 lbs. of coal, whose probable composition was :

Carbon,	89.8 per cent...	4,577 lbs.
Volatile,	5.5 per cent...	281 lbs.
Ash,	4.7 per cent...	240 lbs.

There were withdrawn from the furnace at the end 1,158 lbs., and consumed 3,942 lbs.

Probably all the volatile products were expelled, as the whole material was heated above a red heat, and therefore the carbon consumed was only ($3942 - 281 =$) 3661 lbs., being ($3661 \div 3942 =$) 92.8 per cent. of the combustible consumed in place of 95 per cent., as in the combustible in the coal. The coal burned during the experiment gave evidence of a considerable gaseous component.

In place of a glowing mass of white hot coals, as is the usual appearance of anthracite, the whole fire-box and space was filled with a mass of yellow flame. It is supposed that a part of this flame was the result of an insufficient mixture, not an insufficient supply, of air, and that this mixture would have been aided if the holes provided in the furnace doors had been left open.

These holes were, contrary to the advice of the Committee, kept closed during the whole experiment.†

At about 10.30 P. M., while the fire box was filled with yellow flame, a bucket of water was thrown on the hot ashes in the ash pit under the grate. This water was instantly transferred into a cloud of steam, which passed through the coal into the furnace with considerable force.

The entrance of the steam was immediately followed by a loud explosion in the furnace of sufficient violence to force open the door, which was closed but not fastened, and to drive out a mass of flame a yard long through the furnace door, and *through the fissures in the front* into the fire room.

The manner of connecting the lower rows of tubes of the boiler left openings between the heads, these openings being fissures 12″ to 14″ long, and of sufficient width to see through into the furnace. These fissures must have allowed a considerable volume of air to leak through into the nest of pipes. If this same quantity has been admitted into the furnace where the gases were sufficiently hot to unite with the oxygen of the air in the same manner, it would probably have aided combustion, but being admitted after they had lost a large part of their original temperature by passage through one row of tubes containing water at 35°, the effect was probably injurious to both the economic and potential effect.

It appears from inspection of the foregoing that about 36 per cent. of the air passing up the chimney passed through the fire, being ($10234 \times .36 =$) 3684 lbs. per hour, and ($3684 \div 183.5 =$) 20.75 lbs. of air per lb. of combustible consumed.

This is probably ($20.75 \div 11.5 =$) 1.98 times the air necessary for perfect combustion, as has been found in many other cases.

This coincidence is cited, not to prove the quantity of air passed through the coal, but as the quantity of air passing through the coal, being the balance after deducting the other losses, appear to be what it is well understood it must have been, to prove the correctness of the computation of the *volume* of *air* and the *leakage*.

The amount of air leaking in through the front must have mixed with the products of combustion soon after passing through the three lower rows of tubes,

* Ex. Researches on Steam Engineering, Vol. I., page 275.
† Ex. Res. Steam Engineering, Vol. I., page 146.

and must have reduced the temperature of the products of combustion to the temperature at the flue 328° *at once.* It would appear from this that the boiler would have been more efficient if the three upper rows of tubes had been left off, for they only acted to condense a portion of the steam which had vaporized in the lower tubes. This would not be true if the front were tight.

It will be observed that the temperature of the gas leaving the boiler is less than the temperature of the steam due to the pressure. Under these circumstances, no superheating is possible with any superheater whatever. It will also be observed that at one time the temperature of the gas leaving the boiler is considerably hotter than the temperature due to the pressure of the steam, but the temperature indicated by the thermometer on the steam drum is less than the equivalent temperature of the steam. The following table exhibits this variation :

Hour.	Pressure.	Measure Temperature.	Equivalent Temperature.	Temperature of gas.	Differences.	
					Gas and Steam.	∞ Temp. and Meas. Temp.
9.30	72	319	317.3	350	+32.7	+ 7.4
10.00	73	311.5	318.2	375	57.8	− 2
10.30	78	311.5	328.2	400	77.8	− 6.7
11.00	74	311.5	319.	415	94.0	−16.7
11.30	76	310.5	320 6	390	69.4	− 7.5
12.00	75	310	319.8	390	70.2	−10.1
12 30	80	316	323.6	380	56.4	− 9.8
1.00	70	320	323.6	350	26.4	
1.30	77	311	321.4	330	8.6(+57.8)	3.6(−8.)
2.00	80	319	323.6	310	−22.6	−10.4
2.30	70	307	315.8	320	+ 4 2	− 4.6
3.00	75	312	319.8	315	− 4.8	− 8.8
3.30	79	318	322.9	310	−12.9	− 7.8
4.00	75	312	319.8	310	− 9.8	− 4.9
4.30	84	318	326.6	315	+11.6	− 7.8
5.00	73	310.5	318.5	315	− 3.5	− 8 6
5.30	79	315	322.9	310	−12.9−(10)	8.0(7.64)

An inspection of the above table shows that when the gas was leaving the boiler $57\frac{1}{2}$° hotter than the temperature of the saturated steam, the thermometer in the steam pipe indicated $8\frac{6}{10}$ degrees less than that temperature, and when the steam was leaving 10° colder than the temperature of the saturated steam, the thermometer on the steam pipe indicated only $7\frac{6}{10}$° less than the temperature of the steam. The inference to be drawn from this is that the steam was not *superheated in either case.*

Your Committee do not expect that it can be considerably superheated in any case, because from an inspection of the boiler, it will appear that all the steam formed will pass out through the back end of the lower tubes, and pass directly into the steam drum without entering the superheating tubes at all, and that they will probably be filled with a stagnant mass of steam.

This course of reasoning applies to all boilers of this class which have the steam drum connected with the high end of the inclined tubes. By simply moving the connections and the steam drum to the other end, the steam could be made to pass through the superheating tubes, *en route*, and they would form very efficient superheaters.

Notwithstanding the considerable amount of superheating or steam drying surface, there was a considerable amount of water entrained with the steam.

Your Committee cannot say how much more or less would have been so entrained if the fires had been forced by a stronger draught, so that the gases

would have left the boiler hotter, but it appears probable that there would have been more if the combustion had been more rapid, for during the first part of the first experiment, when the fires were new and thin and burning rapidly, and when the temperature of the gas leaving the boiler was many degrees hotter than the steam, there was nearly 10 per cent. of the water entrained, while the average for the whole experiment was only $2\frac{6}{10}$ per cent.

It will be observed that the per centage of priming is less during the first experiment when the steam pressure is lowest. This is contrary to the generally preconceived idea, and your Committee do not regard this experiment as a final proof of this fact, but have no doubt that the priming was really greater in the case with the higher pressure, for it is shown by the increased apparent evaporation per lb. of combustible, as well as by the measurements in the still.

The diagram of steam pressures, taken by the Edson Time Gauge, a copy of which is annexed to this report, shows that the pressure varied from $8\frac{1}{2}$ lbs. above to $6\frac{1}{2}$ lbs. below the mean during the 1st experiment, and from $7\frac{2}{10}$ above to $8\frac{3}{10}$ below during the second experiment, be a mean variation of $7\frac{6}{10}$, and the air extreme variation of $15\frac{1}{2}$ lbs.

It must be remembered that this variation was, while the feed and volume of steam discharged through the safety valve were regulated to keep the steam as nearly uniform as possible.

The same variations show in the boilers of this class, tested in 1871.* If there had been a constant volume of steam drawn from the boiler, as would have been the case while doing any useful work in a factory, the variation would have been more.

At the conclusion of the experiment, with the steam pressure at 75 lbs., the safety valve was closed, and the steam allowed to accumulate in the boiler until the pressure reached 135 lbs.

During this interval the fires were burning at the same rate as during the other parts of the experiment.

The following table shows the increase of pressure :

Time.	Steam.	Time.	Steam.
hrs. min.		hrs. min.	
5 30	79	5 49	115
5 43	90	5 50	118
5 44	93	5 51	122
5 45	100	5 52	125
5 46	103	5 53	131
5 47	105	5 54	135
5 48	110	5 55	blow off.

The boiler had been fed with cold water just before 5.30, and it is believed that the temperature of the water in the boiler was not uniform until after 5.43, after which the increments of temperature appear to be nearly uniform, being $2\frac{1}{10}$ degrees per minute.

The weight of water in the boiler was 4,400 lbs., and the equivalent weight of iron surrounding it was 1,200 lbs., giving the total equivalent weight of water to be elevated in temperature to be 5,600 lbs. The increase of the temperature of the water was from 5.43 to 5.54, being 11 min., (358.45—331.18=) 27°.25. The units of heat corresponding to this elevation of the temperature of the whole mass would be (27.25×5600=) 178300.

This amount of heat was transferred in 11 minutes. The amount transferred during one hour, at this rate, would have been (178300÷11×60=) 861800 units corresponding to (861800÷1156=) 741 lbs of steam from the temperature of the feed.

But during the interval immediately surrounding the elevation of temperature, the boiler was evaporating (183.5 ×8.8=) 1615 lbs. of steam per hour. If this rate of transfer had continued during the elevation of temperature the increment would have been (2.1×1615÷741=) 4°.4 per minute. So far as this experiment goes, although your Committee do not consider it conclusive, it would appear that the heat was only transferred about one half as fast while the pressure was rising as while it was uniform.*

If the heat should be transferred during the whole time while the pressure was rising to that pressure at which the boiler would burst, at the same rate as during the elevation of pressure between the two experiments, the bursting press-

* Report of Committee on Steam Boilers, 1871.

Heat and Steam Engine. Trowbridge, page 106.

ure would be reached in nearly 23 minutes; for the bursting pressure of the tube is 3,000 lbs., and the temperature corresponding to 3,000 lbs. in 797°, and $(797-320\div 2.1=)$ $22\frac{3}{4}$ minutes. This is about half as long a period as would usually be occupied by the ordinary forms of boiler. The rapid variation of pressure is the result of the small weight of water contained in the boiler. This is an important feature of all the boilers of this class to which this belongs. It must be remembered that the cast iron heads will probably give out a less pressure than 3,000 lbs., although your Committee have no means of determining at what pressure they will give out.

A failure of one of the heads will probably relieve the steam pressure, without causing an explosion in the ordinary acceptance.

The usual way in which boilers wear out is by the burning of the heating surface, where it is covered by a deposit of scale on the water side, or rusting through in places where it is exposed to the air and moisture, as when the iron touches the brick wall, or where any leakage may allow the tube to be continually wet.

In cases where the feed water contains any salts, which are deposited by concentration, or by elevation of temperature scale, will form in all boilers alike, regardless of form or size. The only advantage which one boiler can have over another in this particular, is the facility which it may offer for breaking off this scale, after it has reached a sufficient thickness, to injure the heat transmitting power of the plate. In ordinary tubular boilers, this cleaning can scarcely be done at all, and in flue boilers can only be done very ineffectually, even if the flues are of a large size.

In the Howard Boiler, the whole inside surface of the tubes may be exposed to view by simply removing the caps. A layer of scale of any thickness can easily be removed by driving through the tube a tool with a number of longitudinal grooves, and then breaking down the intermediate portions with a bar. The only portions which cannot be cleaned are the heads, which are but a small part of the heating surface.

SAFETY.

The strength of the tubes of this boiler being $8\frac{3}{8}''$ inside diameter, and $\frac{5}{16}''$ thick, taking the strength of the iron at 50,000 lbs., and the welded joint at 20 per cent. less will be $\left(\dfrac{.80\times 50,000}{8\frac{3}{8}}\times\frac{5}{8}=\right)$ 3,000 lbs. nearly per square inch. The cast iron heads are probably not so strong as the tubes, but the Committee have no means of determining how strong they are.

If it is true, as said by an eminent engineer, that "in nine cases out of ten a continuously increasing pressure of steam without means of escape, is the immediate cause of explosion."* The liability to explosion would decrease as the margin of strength increases, and this must be looked upon as a very strong and safe boiler.

There is another point, however, which the Committee do not feel justified in passing without comment. The feed water is introduced into all the lower rows of tubes from a common pipe, and these tubes are only connected with the steam space by the back end. Now, it is evident that if there is any steam formed in the lower tubes, it must leave them by the back end, and that there would be a constant current of steam leaving the tubes, tending to carry the water with it. It is no doubt the expectation of the builder that there will not be any steam formed in the lower tubes, but that they will only serve as a feed water heater, and that the cold water pumped in at the lower end will be gradually forced along the tube by the fresh supply of water coming on behind it, becoming warmer and warmer as it travels along the tube, but not reaching the temperature of the steam until it arrives at the end and mixes with the water circulating through the upper tubes. So long as this is the case, no harm can come from having *these* tubes connected *at one* end only. The effective surface of the lower row of tubes being one half the total surface, 50 square feet is equal to $(\frac{50}{27}=)$ 1.85 time the grate surface. From experiments with other boilers, at the same rate of combustion, it appears that about 6,000 units of heat would be absorbed by this surface for every pound of combustible consumed. During the experiment, the feed water

* Sir William Fairbairn—Useful Information for Engineers. 1st Series, p. 58. Ed. 1864.

had a temperature of 35°, and each lb. of combustible elevated 9 lbs. of water from the temperature of the feed to the steam, and evaporated 8.8 lbs., the balance, 2 lbs., being entrained with the steam. Thus the total heat absorbed was :

Water	9×286 =	2574
Steam..	8.8×888 =	7814
		10388

Therefore the units of heat available to form steam in the lower tube (6000—2574=) 3426, and the equivalent weight of steam (3426÷888=) 3.86 That is, (3.86÷8.8=) 44 per cent. of the total steam formed in the boiler will be formed in the lower tubes. If the water received heat uniformly from the time of its entrance during its passage along the tube, it would have acquired the temperature of the steam at ($2791 \div 6000 \times 12 =$) 5.6 feet from the front end of the tube at this point the steam would commence to form and the current of water would be reversed.

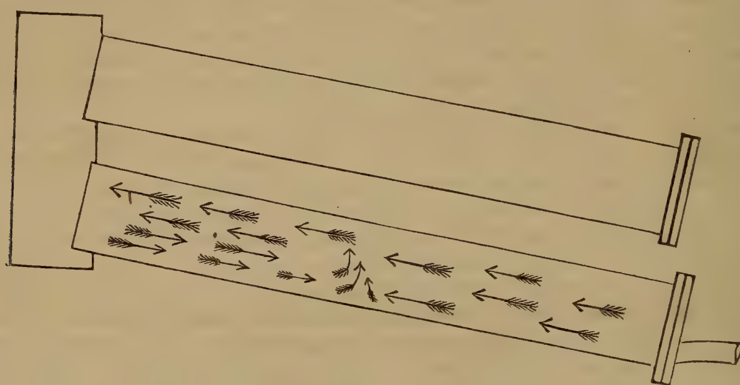


FIG. 14.

If the combustion is slow, as in the experiment, these two currents may pass each other without interference, but if the combustion be sufficiently rapid so that more heat is thrown on the lower tubes, or if the feed water enters the tube at a higher temperature than 35° so much steam may be formed that the opposing currents of steam and water will interfere, and drive the water from the tube when the tube would soon become red hot, and burst with a very moderate pressure. Although it is not probable that there would be an explosion in the ordinary acceptation of the term, still the steam and water would pour out into the furnace with certainly disastrous and perhaps fatal results. Your Committee cannot say at what rate of combustion or temperature of feed, steam would be formed in the lower tubes with sufficient rapidity to expel the water. That can only be determined by experiment, but they refer to the performance of a similar boiler, the boilers of the steam ship "Montana," which would seem to corroborate these views.*

In the form of boiler, at present manufactured by the exhibitors the tubes are connected at *both ends* which would obviate this trouble.

If there were consumed in this boiler ½ lb. of combustible, for every square foot of heating surface per hour, the percentage of perfect absorption would be, computed as in the other cases, 62.4 per cent.

In comparing this boiler experiment with those made under atmospheric pressure, and the ordinary temperature (60°), an allowance should be made for the greater proportion of the heat *necessarily* rejected through the chimney, for the gas must at best be discharged at the temperature of the steam, if there is no feed water heater.

This allowance will be for the Howard boiler under these circumstances of the trial, [(335—35)÷(212—60)=] nearly 2; the heat necessarily wasted in the ordi-

* Nautical Magazine, London, November, 1873.

nary atmospheric test, which is $[(212-60) \div (2240-60)=]$ 6.8 per cent., and therefore in the Howard boiler $(2 \times 6.8=)$13.6 per cent.

That is, if the Howard boiler had been tried under atmospheric pressure, and with an atmospheric temperature of 60°, the per centage of heat usefully absorbed would have increased from 62.4 to $(62.4+6.8=)$ 69.2.

The same reasoning applies to the boilers tested at the Fair, in 1871.

Safety, facility for repairs and durability, are the three most important points of excellence in a type of boiler, for with proper proportions of calorimeter and heating surface all types becomes equally economical.

Your Committee consider that, under ordinary circumstances, this boiler is equal in safety and economy, and is superior, under all circumstances, in durability and facility for repairs to any boiler of its class with which they are acquainted, and they therefore recommend you to award it a *silver medal.*

Your Committee have endeavored, so far as they were able, to anticipate the action of this boiler, and the reasons for its peculiar construction, from an examination of the few sections exposed at the exhibition, but have received in this no assistance from the exhibitors.

Respectfully submitted by the Committee,

R. H. Thurston,
Thos. J. Sloan,
Theron Skeel.

To the Board of Managers of the American Institute Fair.

ON THE CONDITIONS OF WATER BEFORE AND AFTER ITS FREEZING POINT.*

From "Engineering."

Apropos of the question which lately arose from the report of Mr. Lavington E. Fletcher, engineer to the Manchester Steam Users' Association, as to the effects produced upon a boiler filled with water and ultimately frozen, we think that a few remarks upon the condition of water before and after its freezing point, may, to a certain extent, harmonize the diversity of opinion on the subject, which evidently now exists. In so doing we do not pretend to offer any new laws or theories, but by placing before our readers in as concise a manner as the subject warrants, the results of the experiments of such men as Kopp, Despretz, Pierre, Gineau, Regnault, and others, we hope to be able to assist in the solution of a question, possessing unusual interest and importance to the engineer and the physicist.

Although observation and experience, aided by sound inductive reasoning, are the truest guides in experimental researches, we should do well to remember in our investigations the following extracts from Sir Isaac Newton's celebrated *Reguli Philosophandi.* "We are to admit no more causes of natural things than such as are true, and sufficient to explain their appearances." "In experimental philosophy, we are to look upon propositions collected by general induction from general phenomena as accurately, or very nearly true, notwithstanding any contrary hypotheses that may be imagined; till such times as other phenomena occur, by which they may be made either more accurate or liable to exceptions."

All liquids, to a certain extent, expand by the application of heat, and this fact at once shows the fallacy of the commonly accepted notion, that water is incompressible; for the dilation and contraction of the liquid is simply extension and compression of its particles. This subject has been fully investigated in Germany by Kopp, and in France by Pierre; many very valuable and important facts being discovered by their careful investigations. The apparatus used by them was nearly similar, and consisted simply of a water thermometer,

* The Centigrade scale is used throughout.

graduated to the different degrees of expansion; corrections being made in all cases for the expansion of the glass. To determine the compressibility of water still more accurately, Regnault designed a special apparatus, and with it Grassi determined the following results:

Pressure in Atmospheres.	Temperature.		Compression, expressed in Fractions of Original Volume.
	deg. C.	deg. F.	
1	0.0	32	0.0000503
1	4.1	32.38	0.0000499
1	13.4	56.1	0.0000477
1	25.0	77.0	0.0000456

He also found that the compression or condensation of water was proportional to the pressure.

Although the expansion of water is comparatively small between its boiling and freezing points, yet it is the most irregular of all liquids; so irregular in fact, that it has been found impossible to find a single empirical formula to express the expansion at different temperatures. Below 10 deg. C. (50 deg. Fahr.) it is more irregular than above that point, for water possesses what no other liquid has been discovered to have, and that is a point of maximum density. This singular anomaly is so remarkable, and its consequences so important, that we think it advisable to dwell upon it for a short time.

If we take a water thermometer and expose it to the cold, we shall observe the following curious phenomenon. The liquid will gradually descend until it reaches the temperature of 4 deg. C. (39.2 deg. Fahr.); at this point the contraction will cease, and although the cold acting on the bulb is far below this point, the liquid will gradually ascend, until it reaches 0 deg. C. (32 deg. Fahr.), or freezing point, when it will solidify. The point at which the liquid commences to ascend is called its "point of maximum density." An interesting experiment to illustrate this fact, was designed by Dr. Hope, and is as follows. Take a tall jar, and fill it with water, say at 15 deg. C. (60 deg. Fahr.); at the top of the water fix a small mercurial thermometer, and another one at the bottom; then place the jar at rest, exposed to the cold. The bottom thermometer will be observed to fall more rapidly than the top one until it reaches 4 deg. C. (39.2 deg. Fahr.), when it will remain stationary. The top thermometer will now fall, and continue to do so, until the water freezes; the bottom thermometer still remaining at 4 deg. C. (39.2 deg. Fahr.), These effects are easily explained; the particles of water at the top being exposed to the cold, decrease in temperature, thus becoming denser and fall to the bottom, their places being taken up by warmer particles, which in their turn undergo the same change, until the whole volume has completely circulated and attained a temperature of 4 deg. C. (39.2 deg. Fahr.) The particles now, instead of becoming denser, actually expand, and so remain at the top, until a thin layer of ice is formed. This is exactly what takes place in our lakes and ponds every frost, the circulation continues until the whole mass attains the temperature of 4 deg. C. (39.2 deg. Fahr.) when it is gradually and finally arrested; a thin layer of ice is then formed at the top, acting as a cloak to the interior, which remaining always at 4 deg C. (39.2 deg. Fahr.) preserves the animals and fishes from the action of intense cold. Were it not for this fact, our lakes and rivers would all be frozen at the bottom, and as water is such a bad conductor of heat, they would in time be converted into one solid block of ice, which would defy the hottest rays of a tropical sun to melt. Thus we see that such a wise provision of Nature depends entirely on an apparent exception to a universal law, which is so slight that it requires the most delicate experiments to detect it.

This fact was first noticed by the Florentine academicians in 1670, and was carefully investigated at the end of the last century by Gineau, while determining the French unit of weight. His results were confirmed by Hallstrom and Despretz in 1839; but the most recent experiments are those by Plucker and Geissler, and though their results varied between 3.8 deg and 4.5 deg C. (38.8 deg. and 40.1 deg. Fahr.) we may take for all practical purposes, and without any sensible error, 4 deg. C. (39.2

deg. Fahr.) as the point of maximum density.

Having now arrived at the freezing point of water, we will briefly discuss the different phenomena in connexion with it, and sum up with a few of its consequences. The freezing point of a liquid is almost invariably the same as its melting point; that is, if we cool a liquid below its melting point, it will become solid. There are of course many exceptions to this, and even water has been known to be cooled down to 20 deg. C. (4 deg. Fahr.) without freezing. To effect this, however, the water must be kept perfectly still, for with the least vibration congelation commences, and the temperature will instantly rise to zero. An interesting experiment to illustrate this fact, is to take a flask filled with a warm strong solution of sulphate of soda, and allow it to cool in a perfectly still place. The solution will cool down to several degrees below its freezing point, and still remain liquid; if we now sound a deep note on a violin, close to the flask, the whole solution will form almost instantaneously into beautiful crystals, the temperature at the same time rising. If, however, the vibration be not sufficient to cause this change, by dropping the smallest crystal into the flash, the result is almost certain. If we try this experiment we are nearly sure to succeed, but in trying to cool water below its freezing point we very often fail for this reason. The fact that we can do it at all with any liquid, is mainly owing to the inertia of the particles; and as the solution of soda is less fluid than that of water, it is consequently much more inert. By mixing salt with water we lower its freezing point, sea water freezing at—3 deg. C. (26.6 deg Fahr.) and a saturated solution of common salt and water will not freeze until it reaches—20 deg. C. (4 deg. Fahr.) A curious illustration of the fact, that by mixing different substances, we reduce the melting or freezing point below the mean of the two substances, is seen in the common fusible plug, which consists of the following alloy:

2 parts	bismuth, whose melting point is	495° F.
1 "	lead, " " "	612° F.
1 "	tin, " " "	440° F.

The resultant melting point of this alloy is only 96 deg. (204 deg. Fahr.), being far below that of each of its component metals.

When a substance solidifies or freezes, there is always a change of volume, which usually is a contraction; but in the case of water and a few metals, such as cast iron, antimony, bismuth, &c., an expansion takes place. The expansion of water at the freezing point is by no means gradual, but it takes place almost instantaneously, and the amount of force exerted at the time is enormous. After the water has gradually expanded from 4 deg. C. to zero (39.2 deg. to 32 deg. Fahr.), at that point it suddenly increases to about one-tenth more than its volume at 0 deg. C. (32 deg. Fahr.)

Of the enormous force exerted by freezing water, we have ample testimony in the bursting of our water pipes, boilers, and other sadder calamities; but it is a very simple matter to calculate pretty accurately the amount of force developed. We have previously stated that Grassi proved the compression of water to be proportional to the pressure; he also found from very accurate experiments, that with a force of one atmosphere, or 15 lb., water was compressed 0.0000503 of its original volume; and knowing that water exerts in expanding a certain volume, a force equal to the one required to condense it to that amount, the following proportional sum will tell us pretty accurately the amount of force exerted by water when freezing:

As 0.0000503 : 0.1 : : 15 lb. : 29,821 lb.

That is to say in freezing, water exerts a pressure of about 30,000 lb. per square inch, which far surpasses the strain that any of our machinery or structures are calculated to bear, and no wonder then that under its mighty pressure they give way.

We will now say a word or two about the question which really gave rise to this paper, and that is, what are the effects produced upon a boiler, supposing it to be filled with water and left to freeze? We will not make any hypotheses, but think we cannot do better than lay before our readers the result of an experiment that has been tried, and which is so simple that any one can try it for himself, and thus form his own conclusions. A small tin model of a

boiler was made of the following dimensions: length 9 in., diameter 6 in., flue 3 in. diameter, this was filled with water by means of two small taps, one being used to let the air out. When filled the model was carefully measured all over, the diameter of the shell and flue being taken accurately and then placed in a freezing mixture of common salt and pounded ice. In a short time, a slight disturbance was noticed in the box containing the mixture, and it was found that the model was a wreck, the shell having given way at the soldering, the end being partially liberated. The pieces were carefully taken away from the block of ice, and upon coming to the flue, it came out of the block quite easily, and was not bound in the least. Upon measuring the block, the outside diameter was of course larger, but so was the diameter of the flue, showing that there had been no pressure on the metal, as the ice did not anywhere touch it. Upon consideration, we shall find that these results are perfectly in accordance with all the laws we have previously enunciated. As the flue is exposed to the action of the freezing mixture equally with the shell, it follows that a layer of ice is formed around the flue simultaneously with one next the shell. That is to say, the circle of particles around the flue will be increased in diameter, and if the particles in the first instance touched the flue, they cannot possibly do so in their new form. Thus we see that while the circle of particles in increasing its diameter at the shell, tends to burst the boiler; in expanding at the flue, it of course tends to leave it, and the plates and joints of the flue are thus relieved of all pressure. If the pressure were exerted when the water was in a fluid state, the pressure would no doubt fall equally upon the flue, but as the sudden expansion takes place in the act of solidifying, the thickness of the ice increases with the pressure, and thus the flue is gradually protected.

SUPERHEATED STEAM.

From "The Engineer."

If low-pressure steam is to compete in economy with high-pressure steam, it must be used under special conditions. The experience of more than a fourth part of a century has proved unmistakeably, that with saturated steam of 25 lb. absolute pressure, or thereabouts, cut off at half-stroke, in large unjacketed cylinders, we cannot get a horse-power with a much smaller consumption than 5 lb. or 6 lb. of coal. In the face of this fact, it requires, we admit, some temerity to argue that it is possible to work an engine with steam of no greater pressure on a consumption of less than half 5 lb. of coal per horse per hour. Yet it may be shown that, so far as theory is concerned, there is no absurdity about the argument; and it may also be shown, we think, that no insuperable difficulties stand in the way of carrying theory into practice in this case. It is well understood now that there is no source of loss of efficiency which can compare in importance with cylinder condensation. If only steam could be maintained in a cylinder as steam, and not as aqueous vapor or mist, or suspended or deposited water, then the highest degree of economy which theory points out as possible of attainment with any ratio of expansion might in practice be attained. To guard against condensation, cylinders are carefully clothed and jacketed; but even in the most economical engines which it is possible to construct, it is indisputable that a large percentage of the steam admitted to the cylinder is condensed, the condensation having nothing to do with that due to the performance of work. In dealing with this fact we are prepared to admit, that it is impossible for any one to say with precision how much steam is wasted in this way; we have, however, data before us derived from elaborate experiments made with an engine having a 50 in. cylinder and a stroke of 8 ft. 9 in., in which the condensation amounted, when the steam was cut off at one-fourth of the stroke,

to 46.5 per cent.; when the steam was cut off at one-third the loss fell to 28.7 per cent.; when cut off at half-stroke the loss was 25 per cent.; and when the cut-off took place at 58 per cent. of the stroke the loss was 18.74 per cent. The engine used at the last-named point of cut-off 32 lb. of steam per indicated horse-power per hour; so that the loss by cylinder condensation amounted to over 6 lb. per horse-power per hour under the most favorable conditions. The cylinder was well clothed but unjacketed, and the total initial pressure of the steam was 40.6 lb. We could cite other examples taken from various experiments, if it were necessary, all tending to prove the proposition which we are about to put forward—namely, that under most favorable conditions the loss of steam due to cylinder condensation amounts to somewhere between 4 lb. and 6 lb. per horse per hour. We shall not, we think, under the circumstances, err much if we assume that 5 lb. of steam per horse per hour are lost through cylinder condensation alone in high class engines working with saturated steam, and this without regard to the condensation due to the performance of work, but including all steam condensed in jackets. Now it is a very good engine indeed that can manage to get an indicated horse power per hour out of 20 lb. of steam. Of this, 5 lb. are wasted by cylinder condensation in nine cases out of ten. It follows that we burn 20 lb. of coal instead of 15 lb., and that the rate of consumption per horse power per hour is 33 per cent. higher than it might be if cylinder condensation were totally prevented. If we take the 33 per cent. as a factor, and argue that if the best compound engine working with 75 lb. steam wastes 33 per cent. of fuel, we have a margin available to cover losses from any other source in an engine working under different conditions, but in which cylinder condensation does not take place. In other words, if we have two engines, one working steam expansively under given conditions and the other not—the latter, however, not suffering from cylinder condensation—then, unless the gain due to expansion represents a greater gain than 33 per cent. on the working of the non-expansive engine, the latter may prove the more economical of the two. To put this numerically, if the expansive engine uses 20 lb. steam per horse-power per hour, of which 5 lb. are wasted by condensation, then a non-expansive engine using any quantity less than 20 lb. of which none is wasted, will compare favorably with it. We may, so to speak, set the advantage won by averting cylinder condensation against the gain which results from working high-pressure steam very expansively. To make this point perfectly clear, let us suppose that we have a cylinder fitted with a piston having an area of precisely one square foot. Then, if we admit one-eighth part of a cubic foot of steam of 75 lb. total pressure below the piston we can lift a weight of 4147 lb., omitting fractions, through a height of one foot. As used under these conditions, a cubic foot of steam will lift 33,176 lb. a foot high; but we shall assume here for convenience that 60 cubic feet of 75 lb. steam expanded eightfold will develop in round numbers on horse-power. The 60 cubic feet of steam will weigh 10.74 lb. It is well known that it is impossible to get a horse-power in practice out of 10.74 lb. of steam. As we have said, the quantity required in practice cannot be much less than 20 lb. In a very accurate series of experiments carried out with a pair of compound pumping engines at Chatham Dockyard in 1874, the consumption of steam reached 18.92 lb. In one set of experiments with the American steamer Rush with compound engines it amounted to 18.38 lb.; in another experiment to 22.09 lb. If it were necessary we could go on adding example after example to prove that to get a horse-power out of 20 lb. of steam is an exceptionally excellent duty. We shall not attempt to prove here once more that an eightfold expansion of 75 lb. steam gives about the best possible results. We have the difference between 10.74 lb. and 20 lb. to account for, and the sources of loss may be classed under two heads—loss due to wasteful cylinder condensation 5 lb.; loss due to clearance, leakage, steam required to overcome back pressure, &c., 4.26 lb. We are perfectly aware that the loss by cylinder condensation *may*, under certain conditions, with very carefully jacketed cylinders, be as small, perhaps, as 2 lb.

per horse per hour. In such instances, however, the engines are probably working with less than 20 lb. of steam per horse per hour. Thus in the case of the Rush, when using 18.38 lb. of steam per horse-power, 93 per cent. of the water was accounted for by the indicator. The loss by condensation was thus but 7 per cent., or little over 1¼ lb. per horse-power per hour; but when the engines were using 22 lb. the loss reached nearly 25 per cent., or over 5 lb. per horse per hour. It would be but waste of time to adduce further arguments to prove that when an engine is using 20 lb. of steam per horse per hour, one-fourth of the steam is simply wasted in keeping the cylinder hot.

Let us now compare the case we have stated with the conditions which obtain when an engine is working at a disadvantage as regards the pressure and measure of expansion used, but at an advantage in that no condensation takes place in the cylinder. Steam with a pressure of 25 lb. is admitted to a cylinder having an area of a fraction over 1.65 of a foot, and is cut off at one-third stroke. The average pressure will be 17.5 lb., and the work done in lifting the piston 1 ft. will be, as in the first case, 4147 foot-pounds, but the volume of steam used instead of being one-eighth of a cubic foot, will be 55 of a cubic foot, and to produce a horse-power we shall have to pass 264 cubic feet of steam, weighing 16.73 lb., per hour through the cylinder. Now on the hypothesis that no condensation takes place, in this case, in the cylinder, and that the remaining losses will be the same in both engines, we have to add to 16.73 lb. only 4.26 lb., making the total 20.99 lb.—say 21 lb. From this it appears that if cylinder condensation could be wholly averted, a low-pressure engine working with a very moderate grade of expansion would be within 5 per cent. as economical as a high-pressure engine of the best type now in use.

Of course we shall be met at this point by the objection that if cylinder condensation can be avoided in one case it can be avoided in the other, and that the high-pressure engine will still, under the new conditions, be the better of the two; but a little examination of facts will overset this theory. In practice it is found to be impossible to avert cylinder condensation by any known expedient but one. Instead of using dry saturated steam we must use steam gas, or, in other words, superheated steam. But superheated high-pressure steam cannot be used in practice for reasons which are well understood by engineers; and the question has yet to be solved whether it is or is not possible to use it with low-pressure engines. All our arguments are based on the assumption that it is possible, and we shall endeavor in another article to demonstrate this prominently. In the mean time, however, it is expedient to notice the late Professor Rankine's investigation of the properties of steam gas. It will be seen that we claim for it the power of reducing the consumption of steam by about 25 per cent., or from 20 lb. per hour to about 15 lb. Now, Rankine's investigations go to show that when superheated steam is expanded without gain or loss of heat—a condition which may be said to be approximately attained when it is used in an unjacketed but well protected cylinder—the gain under favorable conditions is but 15 per cent. On the other hand, however, he has also shown that when superheated steam is used at a constant temperature, the saving may amount to as much as 27 per cent. It would be impossible at the end of an article like this to deal with the questions which have to be considered in discussing the possibility of using low-pressure steam gas. All that we have endeavored to do, so far, is to prove that if cylinder condensation be averted, low-pressure steam will give as economical results as high-pressure steam, It is not necessary to prove that cylinder condensation cannot be averted by any other expedient but superheating. All experience goes to show that high-pressure highly-superheated steam cannot be used. It is very confidently asserted that the low-pressure highly-superheated steam cannot be used satisfactorily. This last is the question which we wish to see re-opened. We have endeavored to prove that great advantages would be gained in the matter of economy if it can be used. It remains for us to adduce such arguments as we may to prove that superheated low-pressure steam may be used successfully and economically.

THE RUSSIAN CIRCULAR IRONCLADS.

From "Engineering."

The interesting letter from Mr Reed which appeared in the *Times* ought to attract public attention forcibly to the circular ironclads of the Russians, as well as to some other points in their naval system which Englishmen may study with advantage.

Mr. Reed has made it, in fact, the naval question of the day whether we ought not to follow in their footsteps, and build ourselves some of those extraordinary vessels to which the name "Popoffka" has been applied in Russia. The invention of circular ironclads, as is well known, is due to the late Mr. John Elder, but it was left to a Russian, Admiral Popoff, to see its value, and to put it, with some modifications, into practice. Both inventor and adapter appear to be justified by the result, for it seems hardly possible to deny that for a given sum of money an ironclad of much greater defensive power, and of greater offensive power too, so far as guns are concerned, can be produced on the circular than on any other principle.

The Admiral Popoff, the second circular ironclad of the Russians, is 120 ft. in diameter. She draws about 13 ft., and displaces some 3500 tons—a very small displacement for a vessel whose armor is equal to 18-in. plates, and which carries two 41-ton guns. The freeboard is 18 in. only, but the guns are carried in a central tower (which might be a revolving turret if preferred), and deck superstructures may be added to almost any extent. Altogether there seems no reason to doubt her seaworthiness, or even dryness. Her stability, of course, must be beyond dispute, and for steadiness as a gun platform she ought to be unapproachable—the ordinary connection between stability with unsteadiness not existing in the case of vessels of very great breadth and light draught, as has been shown in the American monitors, and more lately in the Dicey steamer. That the Popoffka will be handy to an unprecedented degree is obvious. There is no reason why they should not be constructed as rams, and their extreme handiness and rounded form, as well as the facility with which they can be subdivided internally, should make them safer than most vessels against the attacks of other rams. It is also remarked by Mr. Reed that they lend themselves with peculiar readiness to complete armoring of the sides down to the level of the bottom, should that extension of the present "water-line belt" ever be deemed desirable as a protection against torpedoes. With so many independent propellers and sets of engines the ship can hardly ever be left without motive power, except through absolute failure of coal. As already stated, the draught is light, and, the displacement, or in other words the cost, is very small relatively to the fighting power obtained.

In every point mentioned, and we believe we have named all of any importance save two, the circular ironclad is either equal or distinctly superior to any ironclad of ordinary form and of the same cost. The two points reserved are efficiency under sail, and speed under steam. As to the first, no heavy ironclad can make the slightest pretence to efficiency as a sailing ship, and the most that can be done for any of the class is to furnish them with some kind of jury rig that might (with a fair wind) help them into port after the coals had given out. Unpromising subjects as the Popoffka are for a sailor's enthusiasm, it would probably be possible to do as much for them in this direction as for the Devastation or Inflexible.

The question on which their place in naval warfare really depends is that of speed under steam. The proportion of steam power to displacement in the Admiral Popoff appears to exceed that in the fastest of our modern ironclads, but although the anticipated result is not known to us, we presume the speed will not exceed eight knots, even if it reach that figure. What engine power would be wanted to drive such a vessel at 13 or 14 knots is a question beyond profitable calculation at present, until more is known of the existing Popoff-

ka's performances, but the engines which could give such a result, and the coal which could keep it up for a reasonably long period, could only be carried in a very large and costly ship. Still, the Admiral Popoff displaces less than one-third as much as the Inflexible, and more than 200 per cent. is a wide margin to work with. If any man is bold enough to conceive a Popoffka traveling at 13 knots an hour, let him see what he can produce on a displacement of 11,000 tons. If he can only gain the speed he is sure to beat the Inflexible in everything else. In that case we shall have found our model for "line-of-battle ironclads," and the Popoffka's place in warfare will be a very high one. The coal bill will be heavy, and docks and dock gates will want a good deal of reconstructing, but the model will be found beyond possibility of cavil.

But the circular ironclad may still prove to be the right model for our heavy fighting fleet, even though no such speed as 13 knots be attained or attempted. It is not clear that this high speed—which is about that of the Devastation—is necessary, as we have often pointed out ;and though the question is fairly open to argument, it is possible that to secure such advantages as the Popoffka offer us, we might be content with less—say with 10 knots. If it be possible to build for the cost of the Devastation two Popoffka of only the some armor and guns as the Admiral Popoff carries, and of say 10 knots speed, it is hardly open to doubt which would be the most profitable way of spending the money. A hostile Devastation could elude them of course, but she could not fight them (or either of them, probably) and thus they would have at least the "command of the seas." The French fleet of old were nearly always better sailers than our ships, and for years were able to keep out of our way as they pleased. Yet so little did this answer their purpose that they offered a meeting at last, and were destroyed, and the same thing would almost certainly happen again. If not, it should be remembered that though the best thing to do with your enemy is to take him or sink him, the second best thing, and no bad substitute, is to make him run away. Speed may not be indispensable, however desirable, in a line-of-battle ship.

These considerations as to the employment of circular ironclads as substitutes for the present type of seagoing ships are offered merely to check the too common assumption that they have no claim to attention, except for the purposes of coast defence and attack. We have no wish to drive the argument too hard, or to pretend that such considerations as we have offered are otherwise than speculative, and we do not forget that powerful authorities are opposed to the building of heavy ironclads of any kind whatever—though of those who take this, as we are convinced, grievously and dangerous mistaken view, some might perhaps be willing to accept a sea-going fleet of Popoffka (assuming a sufficient speed) in lieu of the less well-defended ironclads they now object to.

Even more extreme opponents of armor than these appear not unwilling to discuss the merits of the Russian ships for coast defence, so we will next consider them in that character, *i.e.*, as vessels perfectly able to make passages from port to port, or to cross the seas in safety when required, but disqualified by their low speed from the usual operations of sea-going ships.

Our most recent ships of the coast-defence class are the Cyclops and three sister vessels, all of which were commenced on the outbreak of the Franco-German war. The Cyclops displaces 3430 tons, *or about the same as the Admiral Popoff*, has 8-in. and 9-in. armor (with some thinner), and carries four 18-ton guns. Her speed is ten knots and her "coal-endurance" small, though probably this is quite as great as the Popoff's. Her seaworthiness has scarcely been tested, but doubt has been thrown on it. She can certainly move from port to port more quickly than the Russian ship ; but in actual service, say in defending a particular harbor or estuary, or bombarding a fortress, her higher speed would rarely, if ever, give her any advantage. *Au rest*, she has 8-in. armor against 18-in., and (four) 18-ton guns against (two) 41-ton guns, and she draws 15 ft. 6 in. against 13 ft. and is much less handy. The Admiral Popoff would have as much to fear from a

Chinese junk as from the Cyclops, and it is pretty certain that no modification of the latter, no concentration of the guns in one turret, no introduction of coal-tank ends, no shortening and broadening, short of absolute or nearly absolute roundness, could ever put her on a level as to fighting powers with her opponent.

Thus the circular ships appear to be perfect for coast-defence purposes, if it be accepted—as we hold it should be—that speed is comparatively unimportant for such duties. The question of course remains whether we require coast-defence ships at all, or whether our coasts can be better defended by fixed fortifications or by the sea-going fleet. It would be useless at the close of the present article to enter upon the discussion of such a wide question as this—a question, moreover, of naval strategy, not construction. It will be sufficient to say that although, since our coasts are widely different from those of Russia (which are indented with numerous shallow inlets), what may be exceedingly wise policy for her might be foolish for us, our own opinion is that we require a certain moderate number of such vessels for service in the estuaries of the Thames, Mersey, Humber, Tyne, Clyde, &c. The great naval stations like Portsmouth and Plymouth are, or ought to be, sufficiently defended by the fleet and the fortifications, while minor commercial ports can have a cheaper defence in the form of earthworks or Moncrieff gun pits. A dozen circular ships like the Admiral Popoff would be a magnificent addition to the power of the country, and ought effectually to protect all our great commercial ports from injury or even insult. It is not probable that such thoughtful and ingenious men, as the Russian constructors have proved themselves to be, have left any stone unturned to satisfy themselves that the form they have adopted is the best. Substantially (subject to the questions already raised), we have no doubt that it is so, but we should like to know whether the experiment has been tried—or is to be tried—of attaching a wedge or cutwater at each end, sufficient to give water lines making an angle of about 45 deg. with the fore and aft centre line; this would add little to the length of the ship. The wedge-shaped additions might be external to the armor, the circular plan of which would be preserved, and might be used as coal bunkers or coal tank ends. We should not be surprised to find that so very bluff a bow offered practically nearly the same resistance as the round one, but the experiment would be interesting.

THE DELTA OF THE MISSISSIPPI VALLEY, CONSIDERED IN RELATION TO AN "OPEN MOUTH RIVER."*

By JOHN G. BARNARD, U. S. Corps Eng.

Transactions of the American Society of Civil Engineers.

To furnish an outlet to the Mississippi which should evade the bar obstructions of the mouths, a "ship-canal" had been proposed, first in 1832, by Mr. Benj. Buisson, State Surveyor; and again, in 1838, by Maj. W. H. Chase, U. S. Engineers; and the project was referred to by the Board of 1852, as one to "fall back on" in case of failure of all efforts to procure an open mouth; thus placing it in its rightful category of a *dernier resort*. This project was revived by the following resolution of Congress, passed March 14th, 1871:

"Resolved: That the Secretary of War be, and is hereby requested to cause an examination and survey, with plans and estimates of cost, to be made by an officer of Engineers, for a ship-canal to connect the Mississippi River with the Gulf of Mexico, or the navigable waters thereof, of suitable locations and dimensions for military, naval and commercial purposes, and that he report upon the feasibility of the same to the House of Representatives."

* Abstract of a paper presented to the American Society of Civil Engineers.

In the summer of 1873, a Board of Engineers of which the writer was President, was convened "to consider and report upon" a plan which had been in the meantime prepared in fulfillment of the above. The question submitted to the Board was widened by the request of the Chief of Engineers, at the suggestion of the President, to consider "the expediency of improving the navigable outlet of the Mississippi, by the Fort Saint Philip Canal, as an alternative to, or a simultaneous measure, perhaps, with, the improvement of the passes."

The majority of that Board favored the construction of the canal and embodied their views as to jetties in the following paragraph:

"Upon a review of the practical difficulties which the adoption of the jetty system of improvement at the mouth of the Mississippi would entail, and a due consideration of the original cost of construction and of annual extension, entertaining doubts, moreover, of the successful issue of the attempt, the Board do not consider it advisable to recommend it."

The single dissenting member took the ground "that before resorting to an artificial work of the difficult and costly character of a ship-canal, a more attentive consideration of the superior advantages of the natural mouths, and of the fair probabilities of utilizing them, is needed."

And again: "the advantages of an open river mouth are inestimable. The needs of a navigation so great as that which now exists, and which in the future of the great Mississippi Valley must be fifty-fold increased, demand it."

"It is said that the 'time has come' when the needs of commerce demand the canal; but I answer that the *time will come* when there will be the same cry for navigation unimpeded by locks —an *open river mouth*—which we now hear for a canal."

The argument, as put in this last quotation, contains the very pith of the question. No seaport in the world would substitute a ship-canal, with locks, for an open sea entrance, if the latter be not *unattainable.*

Would New York, for example, accept as adequate a ship-canal, for her sole channel of access to the sea? And what limit shall be placed upon the magnitude of the freight-commerce which shall pour out of the great Mississippi Valley through its only outlet to the sea?

A ship-canal can be but a make-shift, a *pis aller*, only to be accepted on *proof* that there is no *reasonable hope* of an "open mouth." How shall that reasonable hope be established save by reference to what *has been done* elsewhere, and by an appeal, not to theories—for theories simply mock the subject by their impotence to grasp the complicated conditions—but to such simple elementary *facts* as may guide our estimate of probabilities? Here all the burden of proof is thrown on the opposer.

To say, in face of the highest authorities* on this subject, in face of *achieved success* in numerous instances, that there *are no probabilities*, or that there are none which justify an attempt which has for its end a result so indispensable to a great navigation, require not merely transcendent engineering abilities—it requires something like *prescience.*

The question is *not*, therefore, purely an engineering one. To fail (if the contingency of failure be admitted) is far from being an *engineering* failure; for the undertaking is not merely justified, but *demanded;* unless, indeed, the engineer can deny even the *possibility* of success.

While no engineer, it is presumed, would trust his prescience so far as to deny *possibility* of obtaining by jetties an "open river mouth," there are a few simple arguments on which to assert—*first*, the strong probability of success; *second*, that the *maintenance* of the accomplished open mouth need not be regarded as involving an unreasonable expenditure or an excessive amount of work.

As to the *first point;* no one, whether "engineer" or otherwise, has yet denied the certainty of *obtaining* by jetties the desired result.

* In Europe, *e.g.*, we have Sir Charles Hartley, engineer of the successful jetty construction of the Sulina; Col. James Stokes, Royal Engineers, British Commissioner for same work; and Mr. P. Caland, engineer of the works at the mouth of the Maas; all advocating an "open mouth" for the Mississippi; nor can the opinions of these eminent engineers be impugned by the allegation that, being foreigners, they are unacquainted with the physical peculiarities of the Mississippi. They have all studied it attentively with access to the most authoritative information; including the work, the "Physics and Hydraulics of the Mississippi."

Hence the *second point* only, requires to be dwelt upon. In the draft of a minority report, dated New Orleans, December 6th, 1873, this matter is thus set forth :

"Now as to the application of this work. For reasons which will appear hereafter, I should select Pass á Loutre for experiment. A glance at the chart will show that from the point in the Pass where the depth of 25 feet ceases to obtain, to the *outer crest of the bar*, is about 2½ miles (at the South West Pass over 4 miles). The natural width of the Pass where 25 feet depth obtains is about ½ mile). * * * By stopping the North Pass, and extending parallel, or nearly so,* jetties which, starting at the cessation of 25 feet depth (above the North Pass), extend, a half mile apart, 4 miles to points opposite the outer crest of the bar, the bar must be excavated to 25 feet (*i. e.*, the 25 feet channel will be extended at once 2½ miles) ; the velocity of current maintained unimpaired up to this point will carry its sediment far beyond, into deep water. The present regime of a shoal bar cannot again be restored, until the vast bottom area now covered with deep water beyond, for a distance of 2½ miles, is raised. That there will be a 25-feet, or even a 20-feet available channel *all* this long time I do not contend. But this I do contend, viz. : * * * that once extended out to the crest of the existing bar, jetties do not require the incessant *following up* supposed ; that they may *ultimately* require extension I do not dispute."

The recent Board of Engineers (of 1874), to which the whole subject was recommitted, used, in giving its decision in favor of jetties, substantially, but quite independently, the same argument, though more fully and clearly developed.

"At present, the muddy water issuing from the South Pass spreads out in somewhat of a fan-shape, the handle of the fan being at the mouth of the pass and the ribs several miles in length."

"If the proposed jetties were instantly completed, and the new channel scoured out, essentially the same amount of sediment would be spread out in fan-shape, but, from the greater velocity of the issuing water, the ribs of the fan would be longer, while the handle would be narrower. More of the sediment would at first be deposited far out in the Gulf than before.

"But with the present rate of advance, the 25 feet curve 120 years ago was about 12,000 feet above its present position ; and if the volume of water carried by the pass is kept the same, neglecting the slight difference in slope of the Gulf bottom outside the present bar, in about 120 years a new end for the pass will probably be formed of the same general shape as the lower 12,000 feet of the present pass. It makes little difference, in the whole time required to accomplish the work, whether the same volume of water flows out at starting over the present shallow bar or from beneath two dikes which force the water to take a depth of 30 feet. In an average of many years, the rate of progress must be about the same as now, namely 100 feet per annum, the volume of water being kept as at present ; and it is on this basis that the average annual cost of extension, namely, $130,000, has been computed.

"It has already been stated that it is proposed to obtain a depth of 30 feet. between the jetties, in order that some years may elapse before the shoal which will form beyond the jetties can have on it less than the required depth of 25 feet in the channel through it. There are no precise data for estimating this period. Going seaward from the upper end of the proposed dikes, the slope of the bottom of the South Pass is about $\frac{1}{440}$. This slope doubtless depends mainly on the velocity of the water flowing through it and on the lifting of the fresh water by the salt. As the causes remain essentially the same, it would seem natural that the new end of the South Pass to be formed by the sediment passing through the jetties should at least have the same bottom slope. If this assumption were true, the bottom would at least shoal from 30 to 25 feet in a distance of $5 \times 440 = 2,200$ feet, and the time required would be about twenty-two years."

Mr. Eads in his pamphlet entitled "The Jetty System Explained" (printed in 1874), pages 6–7, dwells on and develops the same principle, justly reasoning from the facts of nature, that be-

* "Perfect parallelism is not necessary; large deviations may be made to select the best location."

tween the lowest point at which there is 60 feet depth in the South West Pass (whether that *final* 60 feet be in the unmodified pass, or suddenly realized, by means of jetties, on the site of the *present* bar) and a bar having only 15 feet, there must be a distance of 7½ miles—and the *time* for the creation of a new bar (if by jetties the present bar be deepened to 60 feet) must be equal to the number of feet in 7½ miles divided by the amount in feet of the *present annual* advance; a quotient which he assumes to be 178 years.

The arguments are *essentially* identical in all the three independently exhibited forms. These reasons are in themselves the broad and indisputable *facts* of observed configuration. All that has, in a different and conflicting sense, been arrayed is—where not pure assumption—based on theories* which have themselves, no sufficient inductive basis.

But the matter may be somewhat otherwise stated, thus—the passes can prolong themselves no faster than they can build up their base of formation; the broad *bank* on which their bed is laid and that serves as the solid *trough* (as it may be called) which conveys them to the sea. The *front* on which the fan-like expansion over which the great delta arms are laid, has an extent measured on the 100 feet (depth) curve of about 40 miles. The material if all laid *within* (and we know it is transported far beyond) the 100 feet line, cannot advance this front much more than 300 feet per annum. Or if we take the South West Pass by itself (forming a kind of salient on the western extreme of the general configuration) its based measured at the same depth is 10 miles, (even on the 18 feet curve the base is 5 miles,) and this same configuration obtains whether we refer to Talcott's chart of 1838 or the Coast Survey chart of 1867, during which interval there has been a *general* progression of 1½ miles. The side banks, from the pass to lateral deep water, are quite pertinently compared by Mr. Eads to completed natural jetties; and as such, they must complete themselves as they advance. There is every reason to affirm that the advance, whether the material be projected with high velocity over a bar crest 2,000 feet long, or with low velocity over one 11,500 feet long, cannot be made on a base of *less width than we observe to be essential to the natural advance.**

Stress is laid on this exhibition of the case because it discards all theorization, and all subsidiary and disputable questions of "littoral currents," "tide," "winds" or "waves." If in the final minority report of the writer stress is mainly laid upon *precedent*, it is because successful precedent *is enough* to prove the claim that the "open mouth" should be striven for at the Mississippi; and because the greatest possible brevity was aimed at.

It will be noticed, doubtless, that in the passage quoted from the minority report as first drafted, preference is given to Pass á Loutre, not because the analogy between the South Pass of the Mississippi and the "Sulina" (both bearing about 8 per cent. only, of the total discharge) had not already attracted the attention of the writer; but because in sketching out, under great pressure as to time, some outline of an application of the jetty system to the Mississippi delta, it was deemed inexpedient to select an obscure pass—one which has never been known to navigation—for the purpose. Pass á Loutre is, on the other hand, in some degree a rival of the South West Pass, while the application there would involve very much less expense than to the latter. Preference was subsequently given to the South Pass for reasons fully set forth in the minority report.†

In the foregoing, I have endeavored to give a concise history not only of actual operations at the delta mouths, but of the various projects for providing an adequate outlet, whether by operating on the mouths themselves, or by canaliz-

* The two most prominent and sharply defined "theories" of bar formation are those of Mr. Ellett (the vertical *eddy* theory), and of the "Physics and Hydraulics of the Mississippi," pages 445–6, 7, 8, refuting the former and attributing the bar formation to the heavier sediments "pushed along the bottom," but which also calls for "vertical eddies" and a "dead angle, where the river water meets and rises upon the salt water." Were this latter theory *proven*, it would be far from sustaining the inverse rule-of-three computations of enormous bar *advance*, under influence of contraction by jetties, based on it in Ex. Doc. 220, page 31.

* The following from the "Physics and Hydraulics of the Mississippi," page 449, is but another *form* of the above affirmation: "The oscillating motion of waves, when meeting bottom, is changed into a motion of translation, and this tends to arrange the deposit made by the river *into the same gentle slope at which it disposes similar material at corresponding depths along the shores.*"

† Ex. Doc. 220, page 124.

ation. I have, at the same time, endeavored to make plain the grounds on which an "open river mouth" may be confidently hoped for.

In this matter the recent Board (of 1874), in all essential matters, is in unison with me. Its plans or its estimates are doubtless able and thorough, and in absence of any precedent for the kind of work it proposes, are naturally founded on the best foreign precedents, which are those furnished by the practice of Holland, and more especially by recent works at the mouth of the Maas.* These works were visited by me in 1871, and fully described with full details of the facine and ballast construction ("zinc stukken, &c.) in Professional Papers, Corps of Engineers, No. 22, and the methods indicated as likely to "prove especially available in Louisiana." But at the same time they can but serve as *models.* In practice and adaptation to the peculiar locality, I believe they may be much simplified and the desired results of the jetty application be arrived at more speedily and economically than by following rigidly the Board's model.

In all that relates to the rival project of a canal, the recent Board has given incomparably the best solution of that problem yet offered. Nevertheless, while always admitting the *practicability* so far as the mere question of construction (a difficult one though it be), I am far from believing it to offer a reasonable assurance of success, if by *success* it meant the furnishing of an outlet at all adequate; I doubt much, whether in its *working*, it will fulfill even that degree of success which would be justified for similar canals in other localities, and I feel sure it could not be maintained for the small annual sum estimated.

Before closing this paper, I would advert to the case of the Rhone mouth, upon which much stress has been laid as an unsuccessful attempt to apply jetties. I have before me a copy of the "Rapport sur les Projets presentés par les Ingénieurs chargés de la Navigation du Rhone,"* made by a "Commission" of the "Ponts et Chaussées."

Stating that the General Council (*Conseil General*) of the Ponts et Chaussées has already been engaged with this subject in connection with two projects presented by Mr. Surrell, it mentions the *first* as that for a "canal maritime," &c., &c., and the *second*, as one for *concentrating the waters of the Rhone in one single arm*, that of the "Grau de l'Est;" the Council referred to, stating the principle upon which rested this project to be, "that the depth over the bar of a river mouth emptying into the sea is the greater, the greater the quantity of water which is discharged through it."

Thus we find laid down authoritatively, at the very outset of this matter, not the *jetty* method but (see enumeration, page 107, made by the Board of 1852) a distinct and very different one, *i. e.*, that, specified in the words of the board just cited, as "closing the useless passes." And, indeed, through the forty closely written manuscript pages of the report before me, this, and this only, is dwelt upon and discussed in all its bearing, without even an allusion to the very distinct notion of jetties or, as more generally known in Europe, that of "parallel piers."

That the actual construction assumed somewhat the semblance (as far as they went) of "parallel piers," is due simply to the fact that it was deemed indispensable to connect the *dams*, which stopped the "useless passes," by dikes running over the low, intervening islands (*theys*) —that, on the east side it was found easier and more economical to make a *continuous* dike, riverwards of the islands, than isolated dams.

Finally, this Commission, concludes as follows: "Whereas," * * *

"3d. The delta arms (*graus*) of Piémanson and Rouston, which are the first derivations, up stream, from the main river, receive more than half the total discharge.

"4th. That the closing of these arms will constitute a valuable experience from which may be derived useful information.

"Therefore, the works to be executed

* These, even in Holland, were the *first* applications of this kind of work to an *open sea exposure.* So successful has it proved that the lower legislative body of Holland reports that "*the complete success of the works at the Hook of Holland has removed all doubts as to the possibility of making piers at sea*" (*i. e.*, jetties) "*on our coast.*"

The construction, wholly of beton blocks at the sea entrance of the new North Sea Canal, has not proved so complete a success.

* Furnished to Gen. Wright, President of the Board of 1874, by M. Malezieux.

for the improvement of the Rhone mouth should be confined to the closing of the Píemanson and Rouston arms."

The government, however, decided to carry out the plan of Mr. Surrell in full; and now let us hear in the language of M. Malézieux (September 10th, 1874) *what* was done.

The works constructed constitute a continuous dike ("*endiguement*") upon the two banks of the Rhone, from the Tower of St. Louis to the bar; that on the left has a total length ("*developpement*") of 7 kilometres ($4\frac{1}{2}$ miles), and *stops at* 1,531 *metres* (a mile less 80 yards), *inside the crest of the bar*; that on the right has a length of 6,500 metres (4 miles), and stops at 1,460 metres ($\frac{9}{10}$ mile) *inside the crest.* * * * "The result of these works was to *concentrate the waters of the Rhone in one arm*," &c., &c.

And again, the official journal,¶ "Annales des Ponts et Chaussées" (1863, 2d semestre), refers to this matter in these words (translated): "After having attempted to improve the mouth by concentrating all the water *in a single channel*, the administration" (*i. e.*, of the Ponts et Chaussées) "renounced their fruitless efforts and had recourse to the construction of a maritime canal," &c.

It seems scarcely necessary to remark that the jetty system has never been applied to the Rhone mouths. The method of closing useless passes having resulted in failure, the work was abandoned without even an attempt to apply the true jetty system, and the alternative project of Mr. Surrell—a "canal maritime" (ship-canal)—made. This, in the words of the report of the recent Board, "is more than adequate to the wants of commerce." Inasmuch as at that locality there are comparatively trifling wants to be supplied, in *our* sense of such needs, one might suspect a vein of irony in these words, when we consider what a "*canal-maritime*" would be to the wants of commerce of the port of New York. Even *those* wants should not rival the exigencies of the now enormous, but yet undeveloped, freight-commerce of the Great West through its only outlet where the Father of Waters bears to sea the spoils of half a continent!

A METHOD OF PRODUCING PURE CHARCOAL STEEL DIRECTLY FROM THE ORE.

By HENRY LARKIN.

From "Journal of the Society of Arts."

There is no subject in the whole circle of Metallurgical Art in which there exist such differences of theory, and such uncertainties in practice as exist in connection with the very ancient art of making steel. We are not yet agreed even as to the specific compound we shall indicate by that long familiar word. For thousands of years we have been handling steel, for good and for evil, and familiarly speaking of it as if we knew what we were talking about; and yet, even to this day, it remains a mystery. Iron we know, and gold and silver, and perhaps every other metal and alloy of metals in general use, so that, in selecting them, we can define with very great accuracy the precise material we desire to obtain. The value of a bit of gold or silver may, by careful assaying, be estimated with any degree of accuracy that may be desired. The value of a bar of iron, if it be simply iron, is a perfectly known quantity. But with steel it is not so. The moment we pass from the consideration of iron, or of any other simple metal or metals, to the consideration of steel, we pass from terms of scientific accuracy to mere customary phrases of eloquent empiricism. Fortunately, however, with such speculations we need not now trouble ourselves. To an ordinary user and worker of steel a bit of good steel means a material prepared from iron which he can forge into a tool, and so harden and temper as to produce a good working point, or edge, or surface. Until quite

recently the fundamental idea of all steel was tool steel, for piercing, for cutting, and for giving or resisting a blow. Within the last few years, however, a great change has taken place in our ideas on this subject. A new material has been introduced by Mr. Bessemer and by Messrs. Siemens-Martin of extraordinary value for strength and malleability, yet which is neither wrought iron nor tool steel, but intermediate between the two, both in composition and character ; being as much stronger than the one, as it is milder and tougher than the other.

This mild form of cast steel, the manufacture of which has already grown to large dimensions, promises before long to supersede the use of iron for all the more important engineering purposes ; and especially now that Sir Joseph Whitworth has perfected his method of casting under pressure, and thus of producing it as free from honeycomb, and as uniformly sound and reliable as the best wrought iron. But of this giant industry, full of interest for the future as it is, it is not now my business to speak. My present subject is one of far smaller dimensions, although by no means of smaller interest, namely, the good old fashioned tool steel, such as the natives of India knew how to make a thousand years ago, the value of which is not to be measured by mere thousands of tons. Really excellent tool steel may be a comparatively small thing in a commercial point of view, but it stands absolutely alone for value amongst all the implements and utilities of civilized life. We could better part with all the metals ever dug out of the earth than we could part with the steel from which our tools are made. There is not an art, or a comfort, or hardly a mouthful of food that we eat but, in one way or another, is dependent on steel. A good, trustworthy bit of tool steel is simply invaluable. But what shall we say of a bad bit of steel in comparison? There is *no* comparison. The difference is that of opposites ; like that of good and evil, beneficence and malfeasance, like that of trustworthiness and of treachery. There is nothing that man can make more trustworthy than steel, and there is nothing more disastrously treacherous. Man has been wisely defined as a Tool-using Animal. With the exception of a few microscopic rivals and forestallers of our privilege, which Mr. Darwin knows of—Man alone knows how to make tools and how to use them. The highest artist is simply the man who can handle the best tools to the best purpose. The perfection of our tools is but another name for the perfection of our material civilization, and every tool we can lay our hands to is made either of steel or by steel.

Such being the importance of steel, one would have thought among all the developments and applications of modern science, one of the first and most indispensable would have been, to know how to make good steel with the same certainty and uniformity as we know how to make good sovereigns and shillings. But instead of this being the case, I believe I am stating a mere well known fact, when I express my belief that there is not a manufacturer in Sheffield who really knows why his steel comes out sometimes good and sometimes bad. The bulk of our tool steel is still made, not by the light of science, with clear understanding of every step that is taken, but by the merest technical routine and rule of thumb.

Some three or four years ago I was ambitious enough to hope that I might do some little to correct this anomaly. It seemed to me that the production of steel must necessarily be an uncertain thing so long as the ordinary routine of doing and undoing—of smelting, and puddling, and converting, and sorting by rule of thumb was concerned. While occupied with these speculations, I was so fortunate as to obtain a few tons of the well known magnetic iron sand to experiment with ; and my thoughts were —Here is a perfectly uniform material, free from impurity that would be injurious to the steel which might be made from it. If I can succeed in converting this material into steel by the agency of pure carbon and by strictly uniform treatment, I ought to succeed in producing a pure and uniform steel. My notion was, to thoroughly mingle the powdered ore with powdered charcoal in accurately regulated proportions, and then to reduce it in closed retorts at the lowest practicable heat, so as to prevent the reduced metal from cohering to-

gether. I saw from the first that if I could only obtain the reduced metal in a pure and powdered condition, I should have no difficulty in mixing together any reasonable bulk of such powder, so as to be uniform throughout; and that I could, by analysis or other experimental test, ascertain accurately what the entire bulk consisted of, and so know perfectly the material I was to work on. The next step I proposed was to prepare the material so obtained for being melted into cast steel of any required quality, by adding to, and intimately mingling with it just so much carbonaceous material as should be found necessary. This uniform mixture would only then need to be uniformly melted and worked; and, so long as the operations of nature are uniform, the result obtained could be no less so. Such was the origin of my method for making pure charcoal steel directly from the ore: which method, after the usual experiences of long months of disaster and disappointment, I have now the great privilege of explaining, in its matured and I modestly trust triumphant condition.

Before, however, proceeding any further with this explanation, it would probably be of some interest, and certainly will be only fair to my less fortunate predecessors, if I give a short sketch of what, almost unknown to me at the time I speak of, others have done or have proposed to do towards the solution of this interesting metallurgical problem. In order to keep any subject within reasonable limits, I will confine my notice strictly to the various attempts which have had for their leading principle the reduction of iron ores at a comparatively low heat in closed retorts. It has long been familiarly known that iron ores could be reduced at a heat very much lower than that needed for the fusion of the metal. In fact cast iron and cast steel are quite modern inventions. Originally all iron and steel was produced at such comparatively low temperatures, and worked only at a welding heat. But the idea of reducing iron ores at a low heat in closed retorts belongs, I believe, entirely to the present century.

So far as the records of the Patent-office inform us, Mr. William Neale Clay seems to have been the pioneer and first actual worker in this enterprise. In the year 1837 he obtained a patent for "Improvements in the manufacture of Iron." In his specification he speaks of the difficulty then experienced in smelting the richer kinds of hematite ores, which could only be done by "mixing them with poorer ores at considerable cost." He therefore proposes a method for "working such rich ores, and producing malleable iron therefrom by a very simple process, and at a comparatively small cost." He says:—"I take any quantity of red Lancashire or Cumberland ore, or other ores of a rich character, and break the larger lumps, by means of a pair of rollers or otherwise, to about the size of walnuts, which I believe to be the best size for working. With one hundred parts by weight of such broken ore, I mix twenty parts of clean dry coal ashes, or cinders, or of coke, charcoal, charred peat, anthracite coal, or other suitable carbonaceous matter, broken so as to pass through a sieve of half-inch mesh. The mixture is put into retorts or vessels, which I prefer to be of a ∩ shape, about seven feet long, and eighteen inches high, and two feet wide, made of clay, fire-bricks, iron, or other suitable material." There is no special arrangement for heating the retorts, beyond causing the waste heat from a puddling or other furnace to pass through flues carried transversely beneath a row of such retorts, placed side by side, seemingly, from the drawing given, to the fabulous extent of some fifteen or more. It is quite certain that no such extensive arrangement of retorts was ever actually worked on this plan; but it is no less certain that Mr. Clay did really obtain a remarkable degree of success by his very simple, although crude arrangement. His retorts are shown as opening only at one end. Through this opening the mixture of broken ore and carbonaceous materials was shoveled into the retort, which when thus filled was closed by means of a movable door. After the mixture had been kept at a full red heat for a sufficient number of hours to insure the reduction of the ore, the door of the retort was removed, and the charge withdrawn into an empty iron barrow run alongside to receive it. It does not appear what precaution was taken to prevent the expos-

ure of the red hot reduced material to the oxygen of the atmosphere. We are only told that when malleable iron is required, "the charge on being withdrawn from the retorts may be immediately conveyed into a puddling or balling furnace." The completion of the reduction was to be discovered "by taking out some of the pieces of ore from the retorts by means of a pair of tongs, and with a file filing the surface of such ore to ascertain whether it had arrived at a metallic state."

No further patented attempt of any note seems to have been made towards the solution of our problem until 1854, nearly seventeen years later. In that year a patent was obtained by M. Chenot, the scope of which was very much wider and more ambitious. He proposes to make what he calls "metallic sponges" from rich iron ores by reducing them in closed furnaces by the agency of pure carbonic oxyde. This pure carbonic oxyde is to be expressly manufactured for the purpose in the first instance. It is then used for the reduction of the ore, during which operation it takes up another atom of oxygen, and becomes converted into carbonic acid. This carbonic acid is carefully collected as it passes from the reducing chamber; and a sufficient portion of it is reconverted into carbonic oxyde by causing it to pass through "a retort containing carbonized matter at an incandescent or red heat." By this means he says: "I obtain a rich source of pure carbonic oxyde; and the use of gas, which has hitherto been impracticable, is made very easy and effectual." If, however, the ore from which the "metallic sponges" are thus made should not be of sufficient purity to produce metal of the quality desired, "the sponge is to be pulverized by any suitable apparatus, and after pulverization the matter passed to an electric sorting machine." No intelligible working description is given of this "electric sorting machine;" and the only novelty claimed for it is "the use of electro-magnets, employed to sort in a continuous manner," instead of "natural or permanent magnets, which have been used on a small scale to free brass filings from particles of iron." Nevertheless, the idea of applying it to such a purpose is of undoubted value, and M. Chenot is fairly entitled to the credit of having proposed it. Another idea of at least equal value is that, after the "metallic sponge" has been pulverized, and thus freed from extraneous matter, the metallic powder may, if necessary, be intimately mixed with carbonaceous matter and compressed into any desired shape. It is very singular that the value of this idea of mixing powders was so little appreciated that it is actually added as a kind of second best expedient. It seems not to have occurred to the writer that when he had thus got his materials into a powdered condition he could mingle them as accurately and as uniformly, as if they were so many liquids. His main idea runs entirely on the singular advantages of the spongy condition. He says that if the ore be sufficiently pure "it need not be pulverized, and as the sponge properly prepared is porous, that property is used thoroughly to incorporate with the sponge the carbon necessary to the constitution of steel. To this effect the sponge is plunged into a fatty preparation, whose composition is calculated according to the density or absorptive power of the sponge, which latter absorbs equally throughout, and the excess of fat is driven off by distillation almost carried to carbonization, and the sponge then contains all the constitutive parts of the quality of steel desired, the hardness of this steel varying according to the density of the fatty preparation employed. This method constitutes an entirely new principle, by means of which I obtain carbonate of iron with exact doses of carbon incorporated throughout its mass without the use of heat.' There are many other ideas put forth in this specification which I need not specially refer to. The two points which seem to me to be really interesting, or at least which in any way anticipate my own method, are those which I have mentioned, namely, the "electric sorting machine" and the occasional pulverization of the "metallic sponge" and its subsequent compression in moulds. There is no detailed description of any furnace or other apparatus by which the ideas are carrried into practical effect, and there is very little that gives one the conviction of its having been written from actual working experience. In all cases, "metallic sponge" is M. Che-

not's leading thought; and he only proposes to pulverize it when it proves otherwise unmanageable. This metallic sponge he proposes to melt into steel, either in a cupola, stratified with carbonaceous material, or in crucibles, or in the open hearth of a reverberatory furnace.

The next patent bearing directly on our subject is dated only a few weeks after M. Chenot's. This is also by a French gentleman, M. Bellford. The specification describes a very elaborately arranged furnace, in which reducing, refining, and melting are all carried on in a continuous series of operations, without allowing the material to cool down in the process. But the entire arrangement is ingeniously hypothetical and quite impracticable. The one point of interest for us is that "the ore from which the steel or wrought iron is to be produced is first pulverized in a sufficient manner according to its general character, and next intimately mixed with charcoal or other sufficiently carbonaceous matter."

After this, curiously enough, there is another interval of seventeen years before the records of patents show any renewed activity in our special direction. In 1871, Mr. T. S. Blair, of Pittsburgh, Pennsylvania, obtained a patent for "Improvements in the means and apparatus for the reduction of Iron Ores, and for preparing the same for reduction." The specification describes very clearly two ingenious and perfectly distinct arrangements of apparatus for exposing finely pulverized iron ores to currents of heated reducing gas. Nothing is said as to how the spongy iron thus produced is to be utilized; and I am unable to say whether either arrangement has stood the test of actual trial. But the probability is negative, as in 1872 Mr. Blair again comes forward with a patent for "Improvements in the manufacture of Iron and Steel, and apparatus therefor," the apparatus therefor consisting of a third arrangement of reducing furnace, much more elaborate than the two previous arrangements, and altogether different. This last improvement consists essentially of an arrangement of upright cylindrical retorts, about thirty feet high, and three feet internal diameter. The ores is to be fed in with carbonaceous matter at the top, and, when reduced, to discharge itself by its own weight, cold, from the bottom: the reduction being continuous, and the retorts kept always full. This idea of continuous reduction in upright retorts is rather taking in its simplicity, and was already adopted by M. Bellford in his special apparatus; but there are serious objections to it which will be considered presently. In this third arrangement of furnace Mr. Blair proposes to use as his reducing agent, either solid carbonaceous matter, or "gas flames rich in carbon." But, he adds, "when the carbon is supplied in a solid state (as charcoal, coke, &c.), the mixture to be treated will be found a bad conductor of heat, and if the process were conducted in a chamber of large area it would be impossible to convey to the central portion the necessary heat, so as to perform the work with regularity all through the mass. Hitherto this difficulty has not been successfully met. My improved method, which may be called 'initial heating,' removes the difficulty altogether."

If this were true, Mr. Blair's triumph would be great indeed. But this notion of the importance of "initial heating" is based on a very evident fallacy, the fact being that the real pinch of the work lies in the final, not at all in the initial heat given to it. Mr. Blair has devised what appears to be a sufficiently effective arrangement for bringing the upper part of his furnace to a full reducing heat, and he seems to think that having once thus started the operation, he has only to let the material slip down into the body of his furnace with a very moderate supply of extraneous heat, when the process of reduction will continue of itself! I read many months ago, in an American periodical giving an account of the exceeding economy of Mr. Blair's process, a distinct statement to this effect, namely, that the very operation of reduction, when once started, generated sufficient heat to secure its continuance, if only the inevitable loss by conduction and radiation were compensated by some small external supply. If this were in accordance with the facts, I should have to congratulate Mr. Blair on the efficiency of his furnace arrangements; but unfortunately the fact is ex-

actly the reverse. The act of reduction, whether performed at a red heat or at a melting heat, absorbs heat instead of generating it. In fact it is a cooling operation, and not a heating operation at all. It is true the carbon consumed is half burnt into carbonic oxyde, and a certain equivalent of heat is thus set free; but simultaneously the oxyde of iron has to be wholly *un*burned, and a certain proportion of heat must as inevitably disappear. It is to supply this constant absorption during the whole operation of reduction, and, as it were, to compel the oxygen to leave the iron and put up with the carbon, that the heat of the furnace, so long as the reaction is to continue, needs to be kept up to its full efficiency by an extraneous supply. The notion of this process of reduction of iron when once fairly started, going on pretty much of its own accord, is, alas, but another instance of the "perpetual motion" futility, that brightest hope of the unregenerate human heart, to persuade nothing to bring forth something!

I have no hesitation in saying that any possible improvement in the "initial heating" of our materials, instead of removing the difficulty altogether, would be a matter of little or no importance to the success or the economy of the operation. The initial heat may be a very dull red, without involving much loss of time. The first half of the oxygen is very easily and quickly got quit of. The iron at first seems ready enough to part with it; but it is very different when it comes to its last gasp. Then comes the real tug of war between iron and carbon; and nothing short of full red heat, with clear preponderance of carbon, would ever compel the iron to quit its final hold.

I said there were serious objections to upright retorts for reducing. I do not pretend to imply that these objections cannot be fairly met. But to give my objectors every chance, I will briefly state my experience; for I have tried both methods. In the first place, I have not found the force of gravity to be at all sufficient to be depended on to clear them effectually. If the heat be raised a little too high, portions of the reduced metal are constantly liable to stick to the inside of the retort, and need to be thoroughly cleared off, or they would become more and more firmly adherent, until they formed a very serious obstruction. With a horizontal retort, in which each charge is entirely removed before another is introduced, this presents but little difficulty. But with a perpendicular retort, acting continuously and always kept full, it seems to me the difficulty would be insuperable. And Mr. Blair himself ominously admits that "the heat should be carefully kept at the required degree, which is a fair red tending toward yellow, as a higher heat makes the sponge sticky, and gives rise to trouble."

In the next place, even if the material did not stick very tightly to the retort, but the heat were only so much in excess as to cause the material to cohere together but slightly, and this is a thing which would be sure to happen occasionally, the thoroughfare would be inevitably blocked, and the furnace would cease to be self-acting. Lastly, even if the whole contents of the upright retort were periodically cleared out, as in the case of the horizontal retort, it seems to me, as an eye-witness of the difference, that the punishment the workmen would experience in standing over the mouth of a red hot retort to clean it, compared with that of standing at a moderate distance in front, would be alone sufficient to decide the question of their respective efficiency. Of course, in judging of what I now say, every needful allowance will be made for any possible bias of a rival patentee; but I am unconscious of having said one word from a wish to disparage any just claims on the part of Mr. Blair. I fully admit the great ingenuity of his inventions; but I do not believe in their practical value, and if I am to speak of them at all, I am bound to say so frankly. Mr. Blair has a further patent, two years later, in which he claims "the producing cast steel in the open-hearth process by the treatment of iron sponge with admixture of carbon and agents for accelerating carbonization," instancing "yellow prussiate of potash." But in this idea he was anticipated twenty years before by M. Chenot, who, in describing his methods of carbonizing iron sponge for the production of cast steel, either in crucibles or on the open hearth, says: "the carbon may be

found in any powdered carbonaceous matter, or derived from salts of iron, of manganese, or of other metals, from alkalies in the state of cyanides, or from cast iron."

We must now return to the year 1872, in which year our American cousins seem to have been especially alive to the importance of the problem now under consideration. A few weeks after the date of Mr. Blair's principal patent, a patent was obtained by Mr. Joel Wilson, for "Improvements in Furnaces for deoxydizing Iron Ores preparatory to their being worked into Wrought Iron." The specification describes a circular arrangement of upright retorts for the continuous reduction of the mixed materials, the main object of the invention being a more efficient and economical method of heating the same. In the same year a patent was obtained by Mr. T. R. Scowden, also of the United States, for "Improvements in the manufacture of Steel, and in apparatus employed for this purpose." This invention relates to "apparatus by means of which articles of iron have their exterior portions or entire substances converted into steel, by treatment with hydrocarbon vapor, and heat;" and consists further in the application of the same arrangement to the conversion of spongy iron into spongy steel.

In 1874 a patent was obtained by Mr. N. W. Wheeler, of the United States, for "Improvements in the art or process of reducing iron and other ores, the production of Steel, and in apparatus for the practice of the same." According to this invention, "ore in form of sand or powder is let fall in a shower down a shaft, having the upper part filled with a column of heating and even oxydizing flame, and the lower part filled with a column of reducing gases, so that the particles fall first through the flame, and during such fall become heated to fusion or incandescence; and afterwards entering and falling through the reducing gas, yield up their oxygen to the carbon or hydrogen, and thus fall in a reduced state into a hearth or crucible at the bottom of the shaft."

Two days later a patent was obtained by Mr. Edgar Peckham, of the Uuited States, for quite an assortment of improved reducing furnaces. On this elaborate specification the only concise account I can give is, that it consists of fifteen pages of printed matter, and is illustrated by twenty-four very carefully prepared drawings. For further particulars I must refer to the document itself, for I can give no sufficiently brief description that would be of any value of the several arrangements proposed.

I have now indicated as concisely and as faithfully as I am able all the various proposals bearing on our subject which have been patented in England. And I believe I have frankly stated all the points in which I found that my own ideas have been anticipated. But I must add, not one of the specifications referred to shows any recognition of the facilities afforded by the powdered condition of the materials for accurately mixing, and for obtaining precision and uniformity of result. And, accordingly, not one of them proposes to begin with for reducing, a uniform mixture of powdered ore and carbon; and to end with for melting, a mixture of uniform metallic powder, with accurate proportions of whatever other powdered material may be necessary to produce the quality of steel required.

The list which I have gathered is the result of several days' very close research at the Patent office, and I trust that no patent of any real importance has escaped my notice. No one of course is bound to take my judgment on the several proposals as in any way final. I have in each case given both name and date when referring to a patent, and it will be a comparatively easy task for any person desirous of pursuing the matter to recur to the original specifications and judge for himself. For my own poor judgment, I must say they nearly all seem to bear the marks of having been chiefly, and in some cases entirely, worked out on paper, instead of through the disastrous yet wholesome discipline of actual experience. With the single exception of Mr. Clay's patent, taken out nearly forty years ago, I doubt whether one of the arrangements so elaborately described on paper has stood the test of six months' good work actually done. M. Chenot's specification is, for the value of his suggestions, worth all that I have ever read on this subject. But his proposals, valuable as

they are as suggestions, are very far from being carried out into working detail; and it is hardly to be wondered at, that a mind which could aim simultaneously at so many good things, should have practically missed them all. I believe the one secret of success in all such unknown enterprises is, to stick pertinaciously to one thing at a time, until you have thoroughly conquered it, and got it fairly in hand. I should be sorry to weary any one with a tedious account of all the difficulties with which I have had to struggle, one by one, in maturing the idea with which I started. That idea I have alread indicated. And in that simple idea I venture to hope I have laid the foundations of a new method of producing steel, by which that seemingly inscrutible metalloid will yet be brought under the control of science, and be obtained in all its useful varieties with clear-eyed accuracy and certainty.

I trust we shall once more be able to produce steel of the purest and very highest character, rivalling even the Damascus and Toledo blades of which history speaks with such enthusiasm, but which, to most modern manufacturers, have become an unimaginable and incredible myth. There was a time when a man could speak of his "trusty sword" as an almost sacred thing, which, while strength remained in his own right hand to wield it, could never fail him; when the proverb, "True as Steel," went home to each man's conscience, indicating to him whatever was most to be depended on in the hour of trial and direst need. The time now is when the high character has almost passed away; when a new proverb, "Treacherous as Steel," would more fitly express the experience of those who have to deal with it. I make bold to hope that we are fortunately destined, sooner or later, to change all that; that we shall all gradually rise to a higher appreciation of the value, not merely of really good steel, but of really good quality in all things; that "True as Steel" will not always continue the unmeaning phrase it now is, but will once more become the expressive symbol of all that is most honorable in our dealings with each other; and that we shall yet practically find, in all that we are engaged in, that business and beneficence may really walk hand in hand together, to the quite infinite advantage of both.

I am very far from boasting that we have already altogether realized this sanguine dream. I know too well how easily the best steel may be spoiled by unskillful manipulation, either in the melting or in its subsequent treatment, to hope that such perfection of results will ever be attained without a corresponding perfection of care and experience in every step of the process. I have no hope of ever being able to dispense with human faithfulness and sagacity; and I cannot confess to even a wish to do so. My utmost thought is to give faithfulness and sagacity a friutful field to work in; and an intelligible method of working, by which good work shall necessarily lead to an equally good result. And this I do claim to have actually done. The Red Moss Metal Company has been working the process on a small, but regular manufacturing scale in Warrington for some eight or nine months, with all the difficulties of inexperience to contend with; and the tool steel which they have produced, for all varieties of temper and purposes, has been pronounced by those who have used it, with but few exceptions, superior to any other steel obtainable: samples of all which are now lying on the table.

It is true that we have made our mistakes and had our disappointments, owing chiefly to comparative inexperience in the melting; but when I say that we do not go in for picked steel, and that the high testimonials we have received are simply testimonials to our average production; and that it costs us no more to produce the best steel than it would cost us to produce the worst; manufacturers of steel will fully understand the importance of such a statement, however little they may as yet be able to credit it.

I said that I began my experiments with a few tons of pure magnetic iron sand. There are many large deposits of this singular ore in various parts of the world. One of these deposits, many miles in extent, exists on the coast of Taranaki, in the northern island of New Zealand; and a few years ago there was a great talk of the wonderful iron and steel that could be made from it. But all these sands, which are essentially disin-

tegrated magnetic oxyde of iron, although specially suited to the process under consideration, are very troublesome to work in a smelting furnace, on account of their liability to choke it. For this reason there has been hitherto little or no market for it, and there has been no encouragement to any one to bring a continuous supply. In consequence, we have not found it prudent to depend on any mere iron sand as the basis of our manufacture. Any rich and pure ore is almost equally available; although there is an advantage in the magnetic oxydes which will appear as we proceed. The ore which we are using comes from Marbella, on the south coast of Spain. It is a magnetic oxyde, rich, pure, and easily disintegrated, and it can be obtained through the Marbella Ore Company regularly, punctually, and in any quantity required.

The large and small lumps of this ore are first passed through the jaws of a Blake's crusher, set as closely together at the bottom as practicable, and the crushed material is sifted as it falls. The coarser portion is then passed through a disintegrator. In this way the whole bulk of the ore is very cheaply and readily reduced to the condition of the iron sand already described. But of course the gangue of the ore is crushed equally with the ore itself; and the next step is to separate the actual ore from all such extraneous matter, and get as nearly as possible a pure oxyde of iron. This is very effectually done by means of a self-acting magnetic separating machine, specially devised for the purpose, and capable of dealing with large quantities of material. In this machine the particles of magnetic oxyde are picked up by magnetic attraction, and carried into their proper receptacle while the refuse is safely deposited in another. Having thus got as pure and rich a material as possible in a powdered condition the next operation is to thoroughly mix with it a sufficient quantity of powdered carbonaceous matter to combine with the oxygen of the ore, and thus effect its reduction. The carbonaceous matter used consists of powdered charcoal and powdered resin, or other suitable bituminous substance, the two being reckoned together somewhat in excess of the oxygen to be removed. This mixture of powdered ore and carbonaceous powders is slightly warmed, and compressed into bricks in an ordinary brick press, and will then be ready for the reducing furnace.

The reducing furnace consists of a series of D shaped gas retorts, with doors to open at each end. These retorts are heated by a fire acting somewhat upon the principle of a Siemens' gas-producer, and are thoroughly supported throughout their entire length by an intricate arrangement of brickwork, which also serves to prevent a too ready escape of hot air into the flue. The burning gases from the fire are also made to completely envelope the retorts by being carried over and under in a zigzag way, thus still further delaying their passage and arresting the heat with which they are charged. Air-holes are opened at regular intervals in order to complete the combustion of the gases as they circulate around the retorts, thus securing the greatest heat where it is actually wanted and also securing complete combustion of the fuel used. I need hardly add that the consumption of the smoke is perfect. There are other points of importance in connection with the furnace, but as they would not help to a clear idea of the method as a whole they may be omitted.

Let us now imagine one of these retorts at an average working heat, empty, and ready to be charged. The door being removed from the feeding end of the retort, a small stack of pressed bricks, consisting of ore and carbonaceous matter, and of bulk to fill the section of the retort, is closely packed on a rectangular plate, and pushed into the further end by means of an iron rod. The iron plate is then withdrawn, leaving the small stack of bricks securely placed. A second and third feed immediately follow, filling the retort, which is at once closed. After having been exposed to a pretty full red heat for nearly twenty-four hours, gas will have ceased to be given out, the carbonaceous matter will have become practically consumed, and the oxyde of iron will have become converted into red-hot iron powder.

The next problem is how to convey this red-hot powder from the retort without exposure to the action of the atmospheric air, and to keep it so till it

is cold. We will now imagine a charge ready for such removal.

Ordinary coal gas is first, by means of pipes provided for the purpose, turned on into the inside of the discharging end of the retort, in order to produce a full outward pressure of gas while the discharging door is removed, the door being at the under side of a projecting end-piece of the retort. This door being thus removed, an iron receiver is brought up closely under the projecting end-piece, and securely supported there. By a similar arrangement of pipes, gas is now let also into the inside of the feeding end of the retort, when the door of that end is quickly removed, and a temporary door with a wide slot halfway down the middle of it, is put in its place. The slot is for the introduction and working of the discharging tools, by which the red hot powder is quickly pushed forward into the receiver placed at the discharging end. As soon as the retort is empty, the gas at both ends is turned off, and the iron receiver containing the metallic powder is removed and kept carefully closed until its contents are cold. When the metallic powder is sufficiently cooled down, and no injury can arise from its exposure, it is turned out of the receiver, and again passed through the disintegrator and the magnetic machine for a final purification. Thus by a few simple and almost self-acting operations, requiring little more than faithful attention and accuracy in weighing and mixing, we are able to produce the pure metallic powder, the value of which I have already sufficiently urged. For the production of tool steel, which is the subject immediately before us, we mix with the metallic powder (besides some small percentage of flux) whatever additional amount of carbon may be needed, chiefly in the form of resin. This resin enables us easily to compress the finished powder into solid cakes, in the same way as the bricks of ore and charcoal were compressed in the first instance. The cakes of finished material are then stacked up, ready to be melted in crucibles in the usual way, with the addition of manganese or any other alloy that may be found advantageous.

If I were now asked for a definition of steel, which should be quite up to the latest development of science and art, instead of venturing upon some high speculative abstraction, I am afraid I should be tempted to modestly reply :— A metalloid obtained from an accurately adjusted mixture of pure iron powder and carbon, perfectly fused with the addition of manganese, either in crucibles or in an open hearth furnace.

PROFILES OF HIGH MASONRY DAMS.

By JOHN B. McMASTER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

I.

THE subject proposed for consideration in the following paper is that of the profile of masonry dams of such height, breadth and general dimensions as would be required for reservoir purposes, or for impounding the waters of rivers and large streams for mill or irrigation use. We would observe, however, at the outset, that as this matter has already been treated with such fullness by several writers, and especially by MM. Delocre and Sazilly—to whose excellent "memoirs" we are greatly indebted—we can hope to add little that is really new, but shall endeavor, by drawing from many sources, to supply our own deficiency, to diminish the errors of others, and thus obtain results very much more accurate than could be derived if we relied solely on ourselves.

Before, however, we take up the consideration of the matter of the form of profile that shall combine the greatest strength with the least amount of material, there are a number of important points to be considered somewhat in detail. Thus, it is necessary, in the first place, that we should know the forces to

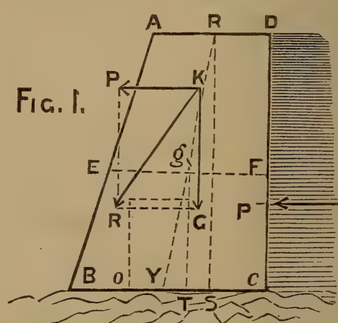
which dams are subjected, their kind, whether constant or variable, the methods of determining their direction and calculating their intensity, and the effects they are likely to produce, and these matters being known, we may pass to the consideration of the conditions of stability, first when the dam has only its own weight to support, and, secondly, when it has to withstand both its own weight and the pressure of the water. We may then deduce a theoretical profile of equal resistance, and, finally, adopt one so modified by the requirements of practice and suggestion of experience, that it shall serve as a *profile type*, fulfilling to the utmost the requirements of great strength and stability, beauty of outline and economy of material.

Now, it becomes evident, after a moment's consideration, that there are but two forces that may at any time be regarded as acting with vigor on a dam, and these are, the weight of the masonry, cement and other material composing the structure, and the pressure or thrust of the water whose flow it checks. The first becomes, to all intents and purposes, a constant quantity as soon as the dam is finished, and continues so for ever after, acting vertically downwards through the centre of gravity of the mass. But, on the other hand, the latter force is one of great variability. For, as its intensity at any moment depends on the depth or head of water behind the dam, increasing as the water deepens and decreasing as the water falls, and the head of water, especially in reservoirs used for mill or irrigation purposes, being subject to frequent rise and fall, it follows that this thrust must be considered as a variable quantity and treated accordingly. It is, moreover, to be observed, that this thrust acts horizontally, and unlike the weight, is not distributed uniformly over the entire face of the dam, being almost, if not quite, zero at the point where the water cuts the masonry, and growing greater and greater as we descend towards the foot of the dam. The weight, it is true, also increases as we go from the top to the bottom, yet, if we suppose the dam to be at any point ten feet thick, the pressure on any horizontal section taken at that point will be everywhere the same, and this is by no means the case if we take an area ten feet square on the water face of the dam, and against which the fluid presses.

In order that the dam may not yield under the first force, and be thrown down by the greatness of its own weight, it is necessary, should the structure be of such height, or the material of such heaviness, that the pressure per unit of surface at any horizontal section is in excess of the "limit of pressure" for masonry, that the surface of the section be increased so that the pressure being distributed over a more extended area the load at each unit of surface shall be less. The second force, or thrust of the water, is resisted at any point by the weight of the masonry above that point, and by the friction of the stones, which is of course dependent on the weight. Some resistance is indeed afforded by the bonding power of the hydraulic mortar used in setting the stones, but this is so small that precautions of safety require that it shall in all calculations be disregarded entirely.

But these two forces, the weight acting vertically downwards and the thrust of the water acting horizontally, counteract each other to a certain extent, and give rise to a third power or resultant, the position of which, as regards the base, will determine the stability of the dam. To illustrate, let A B C D (Fig. 1) repre-

Fig. 1.



sent the profile of a dam composed of horizontal courses of masonry bedded on each other, and K the centre of gravity of the mass, lying above the line E F. Represent by K G the direction and intensity of the weight of A F, and by K P the direction and intensity of the thrust of the water from D to F. Then, constructing in the usual way the parallelogram P K G R, we shall have for the resultant of K P and K G, the line K R.

Now, supposing the dam to be perfectly secure as to its weight, the force P of the water can demolish the wall only, when, exceeding the weight and friction K G, it shoves the mass A F along the joint E F, or causes it to rotate about an axis through E. Which of these motions, the slipping or rotating, shall take place depends entirely on the magnitude and direction of the resultant K R. If the pressure of the water is so large compared with the weight that the angle R K G, which the resultant makes with the vertical, is larger than the angle of friction (32° for masonry on masonry), the mass A F will then *slide* along the line E F; while if the position of the resultant is such that it passes without the base B C, then rotation will take place about the axis of E. Of these two motions, the latter is in practice the most likely to occur, inasmuch as in nine cases out of ten when rotation does take place it does so about some point as E′, nearer the resultant than E, because the pressure concentrated at E, breaks off the stone, and thus throws the axis of rotation nearer the resultant.

The condition of stability then, in dams that do not transmit laterally to the sides of the valley, the pressure they sustain (and this is the case in all large dams) is, that they must resist this pressure at every point by their own weight. If the material employed were of considerable resisting power, as well as the soil of the foundation, and if there were between them an unlimited degree of adhesion, the only condition of stability to be fulfilled would be, as we have just seen, to give the wall such a profile that the resultant of the thrust of the water and the weight of the dam shall pass within the polygon of the base. But this condition is not found sufficient in practice ; the material and the soil of the foundation will, in fact, support only a limited pressure (depending on their nature), and they have not between them an unlimited degree of adhesion. Hence, the two following indispensable conditions :

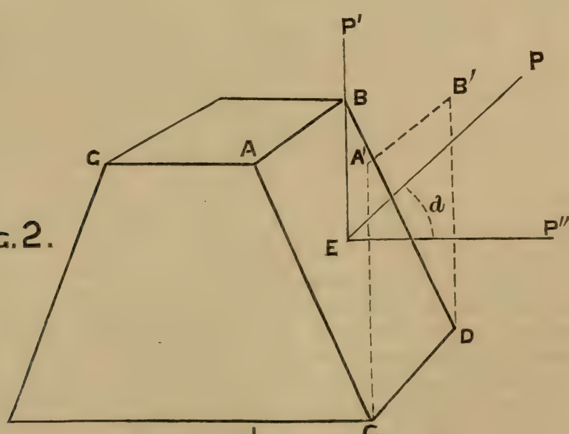
1° The several courses of masonry in the wall must be incapable of slipping the one over the other, and the wall incapable of sliding on its base.

2° In no point of the structure may the material employed, or the soil of the foundation be required to bear too great a pressure. To begin with the first condition.

STABILITY AS TO SLIPPING.

We shall take up first the condition of stability as to the slipping of the various courses of masonry, and then pass to that of the entire dam. The first thing to be now determined, is the horizontal thrust of the water. Suppose A B C D (Fig. 2) to represent the face of

FIG. 2.



a dam pressed by water, and let h=A J denote the height; a=J C the projection of the slope of the dam on the horizontal plane; and, finally, let l=A B denote the length of the dam, and b=A G is breadth across the top. Then will the *vertical* pressure of the water on the face A B C D be expressed by

$$a\,l\,\frac{h}{2}\,y = \tfrac{1}{2}\,a\,l\,h\,y \quad . \quad . \quad . \quad 1$$

and the horizontal *thrust* by the expression

$$l\,h\,\frac{h}{2}\,y = \tfrac{1}{2}\,h^2\,l\,y \quad . \quad . \quad . \quad 2$$

in each of which y denotes the density of the water. These equations are obtained as follows:

Let E P, in Fig. 2, represent the normal pressure of the water on the surface A C, which we will call F, and resolve it into two components, one vertical E P′, and one horizontal E P″, and call them respectively P′ and P″. Then expressing the angle P E P″ made by the horizontal component P″ and the normal E P, by a we shall have from the triangle E P P″

$$\frac{\mathrm{P\,P''}}{\mathrm{E\,P}} = \sin \mathrm{P\,E\,P''} \text{ or } \sin a.$$

But P P″ = E P′ = P′, hence

$$\left.\begin{array}{l} \dfrac{\mathrm{P'}}{\mathrm{P}} = \sin a \quad \text{or } \mathrm{P'} = \mathrm{P} \sin a. \\ \text{In the same way we find} \\ \dfrac{\mathrm{P''}}{\mathrm{P}} = \cos a \quad \text{or } \mathrm{P''} = \mathrm{P} \cos a. \end{array}\right\} \quad . \quad . \quad 3$$

Now, let a projection A′ B′ C D, of the surface A B C D, be made on a plane at right angles to P″, and call the area of the projected surface F′. Then will F′ = F cos A C A′, or since the angle of inclination A C A′ of the surface to its projection is equal to the angle P E P″ = a, between the normal to A C, and the perpendicular to A′ C, we shall have F′ = F cos a or $\cos a = \frac{\mathrm{F'}}{\mathrm{F}}$. But cos a is by equation 3 equal to $\frac{\mathrm{P''}}{\mathrm{P}}$, and therefore,

$$\frac{\mathrm{P''}}{\mathrm{P}} = \frac{\mathrm{F'}}{\mathrm{F}} \quad \text{or } \mathrm{P''} = \mathrm{P}\,\frac{\mathrm{F'}}{\mathrm{F}} \quad . \quad . \quad 4.$$

From the principles of mechanics, we know that the pressure P of water on any given area is the product of the area, the height h of the water, and its density y, so that in the present instance F being the area of the surface A B C D, we shall have for the value of P the expression P = F h y, and this substituted in equation 4 gives

$$\mathrm{P''} = \mathrm{F}\,h\,y\,\frac{\mathrm{F'}}{\mathrm{F}} \text{ or } \mathrm{F'}\,h\,y \quad . \quad . \quad . \quad 5.$$

Therefore is the pressure with which water presses against a surface in a given direction equal to the weight of a column of water, which has for its base the projection of the surface pressed, and for height the depth of the centre of gravity of the surface below the top of the water. We see, moreover, from the above, that since the projection at right angles to the vertical is the horizontal, and the projection at right angles to the horizontal is the vertical projection, the vertical component of the pressure of water against a surface may be found if the *horizontal projection*, or its *trace*, be considered as the surface pressed, and, on the other hand, the horizontal component may be found if the *vertical projection* of the surface, or its *trace*, be considered as the surface pressed.

Applying these two principles to the case of Fig. 2, and replacing F′ in equation 5, by its value $l\,h$, we shall have for the horizontal thrust of the water on the face A B C D of the dam the equation $\mathrm{P''} = \frac{1}{2}\,h^2\,l\,y$, and in the same way the vertical component will be found to be equal to $\mathrm{P'} = \frac{1}{2}\,a\,h\,l\,y$. Now, b being the breadth of the dam, and a' the projection of the slope G K, and y' the density of the masonry composing the dam, it is evident that the area of K C E G will be $\left(b + \frac{a+a'}{2}\right) h$; the cubic contents $\left(b + \frac{a+a'}{2}\right) hl$, and the *weight* $\left(b + \frac{a+a'}{2}\right) h\,l\,y'$. The whole vertical pressure on the base will therefore be equal to this weight *plus* the vertical pressure of the water, or

$$\tfrac{1}{2}\,a\,l\,h\,y + \left(b + \frac{a+a'}{2}\right) h\,l\,y'$$
$$= \left\{\tfrac{1}{2}\,a\,y + \left(b + \frac{a+a'}{2}\right) y'\right\} h\,l \;.\; 6.$$

We have seen, however, that the force which tends to counteract the push of the water, and on which the stability as to slipping must therefore depend, is equal to this weight of the dam increased by the *friction* of the stones. Denoting this co-efficient of friction by f, we shall then have for the force to push the dam forward the expression

$$\left\{\tfrac{1}{2}\,a\,y + \left(b + \frac{a+a'}{2}\right) y'\right\} f\,h\,l$$

and in the case where the horizontal thrust of the water is to effect the displacement

$$\tfrac{1}{2} h^2 . l y + \left\{ \tfrac{1}{2} a y + \left(b + \frac{a+a'}{2} \right) y' \right\} f h l$$

or dividing each member through by $\frac{1}{2} h l y$, we shall have

$$h = f \left\{ a + \left(b + \frac{a+a'}{2} \right) \frac{y'}{y} \right\} \quad . \; 7.$$

In order therefore that the dam may not be pushed away by the water, we must have one of the two following conditions fulfilled; either

$$\left. \begin{array}{l} h < f \left\{ a + (2 b + a + a') \frac{y'}{y} \right\} \\ \text{or } b > \frac{1}{2} \left\{ \left(\frac{h}{f} - a \right) \frac{y'}{y} - (a + a') \right\} \end{array} \right\} \; 8.$$

For safety, we may further assume that the base of the dam is quite permeable, in which case there is (on the principle that a pressure in one direction produces an equal pressure in the opposite direction) a pressure from *below* upwards equal to $(2 b + a + a') l h y$, equal the weight of the dam, and as this is, of course, to be subtracted from the above, we have finally,

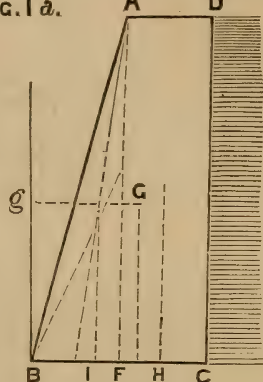
$$h < f \left\{ (2 b + a + a') \left(\frac{y'}{y} - 1 \right) - a' \right. \quad 9.$$

These equations are applicable not only to the sliding of the entire dam on its foundation, but also to any particular layer of stone at any point in the dam. The value of the co-efficient of friction f will of course be very different in cases where we consider the stability of different parts of the wall, from that in cases where we consider the dam to slide on an earthty foundation. In the former case, it is that of masonry on masonry, in the latter, that of masonry on earth, and in general clay. In fact, it may be restricted almost solely to clay, because in a sandy, porous or yielding soil, it is better, on principles of economy, not to build a dam, but a dyke. For masonry on masonry, or, indeed, bricks on bricks, we may with safety take the co-efficient of friction as equal to .67; for masonry on dry clay .51; but for masonry on wetted clay the co-efficient falls to .33.

A few examples may, perhaps, serve to illustrate the above remarks. We shall confine ourselves first to the case of rotation about one of the joints, as that is really the most likely one to arise in practice:

Let Fig. 1*a* represent the profile of a

FIG. 1 *a*.



dam, constructed say of brickwork weighing 112 pounds per cubic foot. Let the thickness on top be 10 feet, and that at the base 20 feet, required to find the perpendicular height, the dam must have in order that, when the water stands at the brim, the wall shall be just on the point of turning about the point B under the pressure of the water. Denote by h the height of the dam, or the quantity we are in search of, = C D. Now, by equation 2, the thrust of the water on one lineal foot of surface is $\frac{h^2}{2} \times 62.5$ lbs., and the *moment* of this thrust is $\frac{h^2}{2} \times 62.5$ lbs. $\times \frac{h}{3}$ or $\frac{h^3}{6} \times 62.5$ lbs. The pressure of one foot of the dam, or what is the same thing, its weight is $\frac{AD + BC}{2} h \times$ 112 lbs., or $\frac{10+20}{2} h \times 112$ lbs. $= 1680\,h$ lbs., and the *moment* of this pressure with reference to the point B is $1680\,h \times BE$. Before we can obtain this moment, then, we must find the value of B E, and this is found as follows:

It is evident from a moment's inspection of Fig. 1*a*, that the area of

$$ABCD \times Gg = \text{area } ABCF \times BH + \text{area of } ABF \times IB, \text{ or}$$

denoting A D by a; B C by b; D C by c; and Gg by d, we have since $BH = \frac{2b-a}{2}$, and $IB = \frac{2(b-a)}{3}$.

$$c\,\frac{b+a}{2}d = a\,c \times \frac{2\,b-a}{2} + \frac{c\,(b-a)}{2} \times 2(b-a)$$

dividing by c

$$\frac{b+a}{2}d = a \times \frac{2\,b-a}{2} + \frac{(b-a)^2}{3}$$

$$\text{B E} = d = \frac{2\,b}{3} - \frac{a^2}{3\,(a+b)}$$

Substituting for the above quantities their values, we have :

$$d = \tfrac{40}{3} - \tfrac{100}{90} = \tfrac{110}{9}.$$

The moment of the dam therefore is $1680\,h \times \frac{110}{9}$.

$$\therefore\ \frac{d^3}{6} \times 62.5 \text{ lbs.} = 1680\,h \times \tfrac{110}{9}.$$

$$\frac{62.5\,h^3}{6} = \frac{184800\,h}{9}$$

$$h^2 = \sqrt{197.12}$$

$$h = 44.3982.$$

Again, preserving the same dimensions, let it be required to find the "modulus of stability" of a masonry dam of the profile, shown in Fig. 1, the stone weighing 200 pounds per cubic foot. Draw from the middle of the top A D to the middle of the base B C the line R V, and take its length as 45 feet, and the depth of the water behind the dam, 44 feet. Now, by geometrical principles, which it is not worth while to repeat here, we have :

$$\text{V}\,g = \tfrac{1}{3}\,\text{R V}\,\frac{\text{B V}+\text{A D}}{\text{B V}+\text{A R}} \text{ or V}\,g = \frac{45}{3} \times \frac{10+10}{15} = \frac{245}{15}$$

g being the centre of gravity of the wall. Again, in the two similar triangles R V S and g V T, we have :

$$\text{R V} : \text{V S} :: \text{V}\,g : \text{V T}.$$

The value of V g we have just found. V S is evidently equal to V C—S C, or $10-5=5$. In the triangle R V S, we also have $\text{R S}^2 = \text{R V}^2 - \text{V S}^2$, or $\text{R S}^2 = (45)^2 - (5)^2$; hence R S=44.38. Substituting these values in the above proportion, we shall have :

$$45 : 5 :: \frac{245}{15} : \text{V T}\ \ \therefore\ \text{V T} = 1\tfrac{2}{3}$$

The weight or pressure of the wall acting through the centre of gravity g of the dam is, as we have already seen,

$$\frac{20+10}{2} \times 1 \times 44.38 \times 200 = 133140 \text{ lbs.},$$

and that of the water $44 \times 1 \times \frac{44}{2} \times 62.5 = 60500$ lbs. If now we denote by P the "centre of pressure" of the water, that is to say, that point where a single pressure will counterbalance the thrust of the water against the entire face D C of the dam, then $\text{P} = \text{C P} = \frac{44}{3} = 14.6$ feet. The quantity we are in search of, the modulus of stability of the wall is the ratio of T B to T O. The value of T B we have already, and may obtain that of T O from the proportion that the pressure of the dam is to the height of the centre of pressure (P) of the water above the base of the dam as the pressure of the water is to the entire pressure of the water acting on its centre of pressure P. Thus :

$$133140 : 14.6 :: 60500 : x$$

$$x = 6.6 = \text{T V}.$$

Dividing this last found quantity by T B, we have :

$$\frac{\text{T V}}{\text{T B}} = \frac{6.6}{11\frac{2}{3}} = .537 = \text{modulus of stability.}$$

In a well built structure, this quantity should never be *less* than .5, hence, as in the present case, the modulus is somewhat above this value, we are justified in regarding the dam as a perfectly stable structure, when the water is not over 44 feet in depth.

In these considerations, we have taken no account of the resistance offered by the adhesion of the mortar. Should this be taken into account—and it is always best that it should not—then equation 9 will require to be modified somewhat as follows : Let H equal the distance of the centre of gravity of a layer of stones below the top of the dam. The shove of the water tending to throw down this portion of the dam is, as we have just seen, $\frac{\delta\,\text{H}^2}{2}$, in which expression δ is merely a short notation for ly. The forces resisting this shove are the friction of the two layers sliding on each other, and the adhesion of the masonry. The first is proportional to the weight of the masonry above the stratum in question, and the second or adhesion of the masonry is proportional to the thickness of the dam at this point. Representing as

before the co-efficient of friction by f, by c the cohesion of the mortar per unit of surface, by s the area of the upper surface of the course next below, and by b the thickness of the dam at this section, we shall have for the resistance R to sliding :

$$R = s\,\delta' f + c\,b$$

and therefore, in order to insure stability, we must have :

$$s\,\delta' f + c\,b > \frac{\delta\,H^2}{2}$$

or clearing of fractions, and then dividing by $\delta\,H^2$,

$$2\frac{(s\,\delta' f + c\,b)}{\delta\,H^2} > 1 \quad . \quad . \quad . \quad 10.$$

Neglecting the adhesive power of the mortar, the above becomes :

$$\frac{2\,s\,\delta' f}{\delta\,H^2} = 1 \quad \text{or } f = \frac{\frac{\delta\,H^2}{2}}{s\,\delta'}$$

The second case of slipping, or that of the dam on its foundation will rarely, if ever arise, when the dam is founded on a rock, for in that case the value of the co-efficient of friction will be the same for the horizontal section of the foundation as for any section of the masonry. It is, however, very likely to arise whenever circumstances will not enable us to lay the foundation on bed rock. In such cases the soil will almost always be of an argillaceous nature, for, should it prove to be of a gravelly, sandy or very permeable character, the employment of some common form of dyke will be much preferable to the construction of a dam. We may, therefore, reasonably assume that in all cases where the foundation course does not rest on a rock surface, it will be laid on argillaceous soil, and as this will readily give, under the action of water, a slippery slimy surface, we must assume a co-efficient of friction very much less than that used for masonry on masonry. With this point kept clearly in view, the conditions of stability will be given by the above equations. Yet there are one or two other considerations that must not be overlooked. Thus, as the stability will depend in large measure on the lateral resistance of the soil, it is not sufficient to be sure that this resistance is large enough to prevent the sliding of the wall, but is also necessary to be assured that at any point of the front of the foundation wall, the normal pressure does not exceed the limit R′ of which the soil or the wall is susceptible. Again, in order to prevent any slipping likely to arise from the lateral compression of the earth, it is not necessary to interpose any packing between the face of the wall and that of the ditch, and, finally, that in all cases it never comes amiss to "step" the rock or the earth on which the foundation course rests, a matter to be considered more in detail hereafter.

SECOND CONDITION OF STABILITY.

To return now to the second condition of stability, namely, that in no point of the structure may the material employed, or the soil of the foundation, be required to bear too great a pressure. For this purpose let A B C D (Fig. 3) repre-

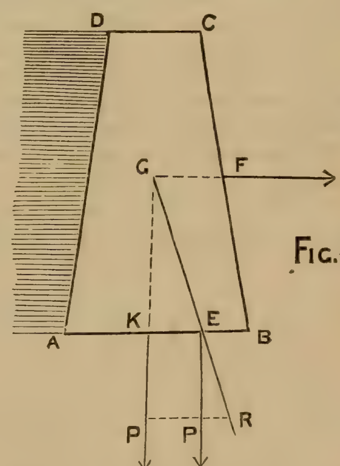


FIG.3.

sent the profile of a dam. Then from the principles we have already established, it follows that any section of this, equal in length to a lineal unit, may be considered as subject to the action of two forces, which are, respectively, the vertical component P of the *resultant* of the weight of the structure above that unit, and the horizontal pressure or *thrust* of the water, and the horizontal component F of the thrust of the water. In the section A B C D, these two forces act through the centre of gravity G, and produce a resultant of their own which cuts the A B at E. This latter resultant R may therefore be regarded as applied directly to the point E, and resolved into

two components, one vertical and equal to the force P, and one horizontal and equal to the force F. The horizontal force tends to slide the wall along the base AB. This we have considered. The vertical spreads itself over the base from the extremity B, which is nearest the point of application of the resultant, according to the well known decreasing law. Now, in all works on mechanics, we have given a formula which applies to a homogenous rectangle, pressed by a force acting upon one of the symmetrical axis, and this is:

$$p=\frac{N}{\Omega}(1+3n)\quad . \quad . \quad . \quad (\propto)$$

and

$$p'=\frac{N}{\Omega}\left(\frac{4}{3(1-n)}\right)\quad . \quad . \quad (\beta)$$

Where N is the entire load or pressure, and Ω the entire area of the surface pressed. In the case we are considering, the quantity N in equations $\propto$ and β, is, of course, represented by P the vertical component. Ω, by l, if by this letter we designate the breadth of the base AB, and if we denote the distance EB by u, then will the quantity n in equations $\propto$ and β be represented by $\frac{l-2u}{l}$.

Substituting these quantities, we shall have:

$$p=\frac{P}{l}\left(1+\frac{3l-6u}{l}\right)=\frac{P}{l}\left(\frac{l+3l-6u}{l}\right)$$

$$=2\left(2-\frac{3u}{l}\right)\frac{P}{l}\quad . \quad . \quad . \quad . \quad . \quad . \quad 11.$$

and

$$p=\frac{P}{l}\times\frac{4}{3\left(1-\frac{l-2u}{l}\right)}=\frac{P}{l}\times\frac{4l}{6u}$$

$$=\frac{2}{3}\frac{P}{u}\quad . \quad . \quad 12.$$

Equation $\propto$ is applicable in all cases where $n<\frac{1}{3}$, and therefore equation 11 is applicable when $\frac{l-2u}{l}<\frac{1}{3}$; that is when $u>\frac{1}{3}l$.

Equation β is applicable to all cases when $n>\frac{1}{3}$, and consequently equation 12 to all cases when $\frac{l-2u}{l}>\frac{1}{3}$, or, what is the same thing when $u<\frac{1}{3}l$. We have seen that the condition of stability requires that some limit, R′, should be placed on the pressure each superficial unit is expected to bear. The pressure at the point B, must therefore be less or never greater than R′, and we shall have according as u is greater or less than $\frac{1}{3}l$,

$$2\left(2-\frac{3u}{l}\right)\frac{P}{l}=\text{or}<R'\quad . \quad 13.$$

and

$$\frac{2}{3}\frac{P}{u}=\text{or}<R'\quad . \quad . \quad . \quad . \quad . \quad 14.$$

And this condition is to be fulfilled for each section made in the profile, neglecting the force of cohesion of the mortar which is unfavorable to resistance.

These expressions are susceptible of yet further modification, if we introduce into the calculation the maximum height λ that may be given to a wall with vertical faces, so that the pressure upon the base shall not exceed the limit R′ of safety. Indeed, if we represent the density of the masonry, or the weight per cubic yard by δ, we shall have $R'=\delta'\lambda$, and the above equation become:

$$2\left(2-\frac{3u}{l}\right)\frac{P}{l}=\text{or}<\delta'\lambda=2\left(2-\frac{3u}{l}\right)$$

$$\frac{P}{\delta' l}=\text{or}<\lambda\quad . \quad . \quad 15.$$

and

$$\frac{2}{3}\frac{P}{u}=\text{or}<\delta'\lambda=\tfrac{2}{3}\frac{P}{u\delta'}=\text{or}<\lambda\quad . \quad . \quad 16.$$

The conditions expressed in these equations would be quite sufficient if the water was always up to the top of the dam, but as this is by no means always the case, the wall must be capable, even when the dam is quite empty, of supporting its own weight without being subject at *any* point to a pressure per unit of surface exceeding the limit $\delta'\lambda$.

In this case the resultant of all the forces acting on the wall is reduced to the weight P′, and denoting by KA, the distance from the resultant passing through the centre of gravity of Fig. (3) to the nearest extremity A of the base, by u, the pressure at A, will be given according to circumstances by equations 11 or 12, and the *stability* of the wall will require that one of the relations expressed in equations 15 or 16 be satisfied when P′ is substituted for P.

The next step, therefore, is to determine the proper

PROFILE FOR A DAM HAVING ONLY ITS OWN WEIGHT TO CARRY.

In order to study under all conditions, the question we are now about to consider, it is perhaps well to inquire, in the first place, what form it is most *convenient* to give a dam having only its own weight to carry, in order that each point of the masonry shall not be subjected to a pressure larger than the limit of safety, and then to determine the alterations which economy require to be made in this *assumed* profile. It is evident, to begin with, that when the height of the dam is such that it does not go over the limit λ (*i. e.* the greatest height we can give to a vertical wall, without the pressure on the base becoming larger than R', we shall be quite justified in giving the dam vertical facings, and that, in such case, the load for each unit of surface at the lower part will be somewhat less than $\delta'\lambda$, or at least, never greater. Again, we know that whenever the pressure on a horizontal surface of masonry is larger than the limit of safety, we may correct this, by enlarging the area of the surface pressed, and so lessen the load on each superficial unit. And these are the two fundamental principles of dam construction, and may be summed up in brief as follows: If we are constructing a dam of a height equal to or less than λ, *and having only its own weight to support,* it is a safe practice to give it vertical facings from top to bottom. If, however, we are constructing a dam of a height *greater* than λ, *yet having only its own weight to support,* we must make the faces vertical for a distance from the top equal to λ, and *from* this point to the *base* slope them *outward.*

A dam constructed on this latter principle would give a profile similar to that in Fig. 4. From the summit A B to the section C D, the pressure per superficial

Fig.4.

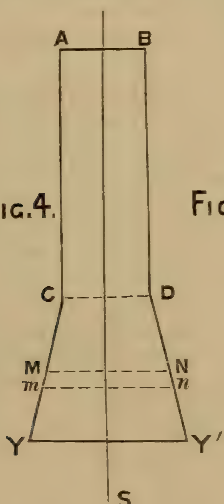
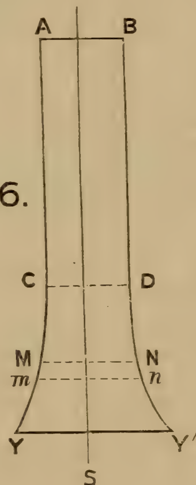


Fig.6.



unit is nowhere greater than $\delta'\lambda$, and therefore from A to C the face is vertical, but *below* C D, the load exceeds the limit and increasing at each section to the base, and hence from C to Y the face is sloping. And just here we are met by the great question in dam construction that of *profile.* Should the bulging portion C Y Y′D, be bounded by right lines as in Fig. 4, should it be *stepped,* should it be curved, and if so, should the bounding curves be logarithmic curves, simple or compound? these are questions we propose to consider.

It is an easy matter to determine the force to be given to the facing, so that the condition that the load per unit of horizontal surface shall never go over the limit $\delta'\lambda$, shall be satisfied. To do this, we may choose arbitrarily one face and then determine the other, but if we desire to use the minimum of material consistent with perfect safety, then the wall must be symmetrical as to its axis. In such a case as that illustrated in Fig. 4—that of a high masonry dam, whose height is greater than λ—the slopes D N Y′ and C M Y, ought to satisfy the

requirement that, if in any section, as M N, the load per surface unit is equal to any given quantity, the pressure will be the same for any other section as $m' n'$, infinitely near to it. This will be fulfilled, if the increase given to the base is proportional to the increase of pressure, or as the profile is to be made symmetrical to the axis O S, if the increase of the half surface L N or L M is proportional to the increase of load on that half surface. If we denote by P the pressure on L N, arising from the weight of the structure above, and a the surface of this section, then, it is evident, the above condition will be expressed by

$$dP = K. da. \quad . \quad . \quad . \quad 17.$$

In which K is a constant quantity, and denotes the limit of pressure on the unit of surface or $\delta'\lambda$. Again, by b, denote the dimensions of the dam in the direction perpendicular to the section we are concerned with, and by x the length of the half section L N, or, to express it mathematically, the abscissa of the curve or line sought (*i. e.* D N Y′), and finally, by y, the distance of M N from a horizontal line taken as the axis of x. Then the surface a will equal to bx, and consequently an increase of surface as $d\,a$ in equation 17, will be expressed by

$$d\,a = d\,b\,x$$

and moreover

$$dP = \delta'\,b\,x\,d\,y$$

These values substituted in equation 17 give for the differential equation of the curve,

$$\delta'\,b\,x.\,d\,y = K.\,b.\,d\,x\,. \quad . \quad 18.$$

whence

$$d\,y = \frac{K}{\delta'}\,\frac{d\,x}{x}$$

But K equals the limit of pressure per unit or $\delta'\lambda$, and this value replaced for K, we shall have

$$d\,y = \frac{\delta'\lambda}{\delta'} . \frac{d\,x}{x} \text{ or } d\,y = \lambda\,\frac{d\,x}{x}$$

Integrating this between the proper limits, we shall have

$$y - y_0 = \lambda \log\left(\frac{x}{x_0}\right) \quad . \quad . \quad . \quad 19.$$

Now, from this equation we see that, the curve being referred to rectangular axes, one of the co-ordinates is equal to the logarithm of the other, and, hence, the curve must be a *logarithmic curve.* Here then we have one property of the curve D N Y. To find in the next place the origin of its co-ordinates, we may make in the foregoing equations $x_0 = \lambda$, in which case we shall have :

$$1 = \frac{d\,y_0}{d\,x_0} \text{ and } y_0 = 0 \quad . \quad 20.$$

From this last relation it is quite apparent that the origin of co-ordinates is to be taken at a point where the value of x is equal to that of λ, and in this point the tangent to the curve makes an angle of 45° with the axis of x. Returning now to equation 19, let us replace y_0 and x_0 by their respective values, given in equation 20, when we shall have:

$$y = \lambda \log. \frac{x}{\lambda}$$

or passing from the system of Napier to the common system of logarithms,

$$y = 2.302658509\ \lambda \log. \frac{x^*}{\lambda} \quad . \quad . \quad 21.$$

This curve, when constructed, will give the form of the facing of a wall of indefinite height for which the pressure per unit of surface equals the limit of pressure K. It is not to be forgotten in in making use of equation 21, that the direction in which y's are usually estimated has been reversed ; in other words, y when positive is to be estimated downwards, and when negative upwards, or in the direction of L O. Fig. 5 represents this curve constructed, by

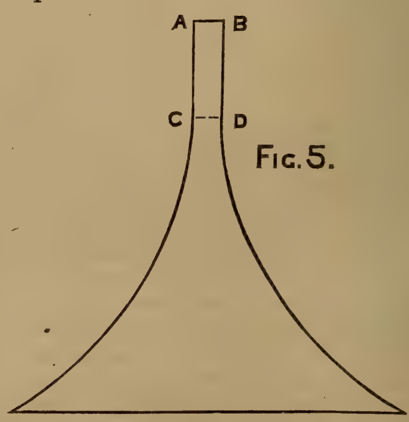


FIG. 5.

* We may also pass from the Naperian to the common system, by multiplying the Naperian logarithm by the modulus of the common system, which is 0.434294. Its logarithm is 9.637784.

assuming the pressure limit or K as 132,000 lbs., and the density of the masonry as double that of water.

In such a profile, as Fig. 4 has, the sloping faces below C D being bounded by right lines, we may obtain the necessary breadth of the base Y Y′, as soon as we have determined the height and the breadth at top. Denote by b the breadth at top A B; by h the distance A C=λ, and by h' the distance from C to the base Y Y′; by δ' the density of the masonry, and by x the quantity we are seeking for, or the base YY′. Then we shall have:

$$\left\{ h \times b + h' \left(\frac{b+x}{2}\right) \right\} \frac{\delta'}{x} = \delta' \times h \quad . \quad 22.$$

The quantity h in this equation, which is merely another expression for the quantity λ, has been determined by a number of investigators, but the most reliable results are those obtained by the French engineers,* who, in the construction of their great masonry dams, such as Furens, have taken the limit of pressure K at 60,000 kilogrammes, or about 132,000 lbs. per square metre, and K being equal to $\delta'\lambda$, and δ' being equal to 2,000 kilogrommes, λ becomes equal to 30 metres. As we shall hereafter see, however, the limit of pressure varies for the outer and inner face of the dam.

If, again, the profile adopted be such as is illustrated in Fig. 3, that is to say, if the faces of the dam slope continuously from the top to the bottom, then the thickness or breadth of the base will evidently be obtained by dividing the product of the height of the wall and its thickness on top by the difference between 2 λ and the height. For $\delta'\lambda$ or the limit of pressure is equal to the area of the profile, multiplied by the density of the masonry divided by the thickness of the base. In the figure, the area is plainly equal to half the sum of the two parallel sides by the altitude, and denoting this latter by H, we shall, therefore, have:

$$\delta'\lambda = \mathrm{H}\left(\frac{b+x}{2}\right)\frac{\delta'}{x} \text{ or } x = \frac{\mathrm{H}\,b}{2\,\lambda - \mathrm{H}} \quad . \quad 23.$$

The conditions which govern the construction of such a dam, and the height to which it is safe to build it, become from this equation quite apparent, should we make H= 2 λ, then x would equal $\frac{\mathrm{H}\,b}{0}$, and the base of the wall would spread out to infinity. Should we, upon the other hand, make H greater than 2 λ, then λ would become negative, and hence it follows that the greatest height we can give to a masonry dam with straight sides equally inclined from the summit and not go over the limit of resistance for masonry, is equal to twice that of a wall with vertical sides. Yet, within this limit, such a profile for a masonry dam of any height, occasions a gross waste of material. This becomes strikingly apparent, if we compare the breadth of base of a dam constructed with inclined faces from top to bottom, with that of a dam of the same height, but having a profile such as that of Fig. 4. Suppose each dam to be 30 metres high and 5 metres thick on top; required the thickness at the base. For the first case, using equation 23, we have:

$$x = \frac{30 \times 5}{60 - 30} = 5 \text{ metres.}$$

For the second form of profile, we use equation 22, and have, since the quantity h equals λ, the same value, or x = 5 metres.

If we raise the dam by 10 metres, then equation 23

$$x = \frac{40 \times 5}{60 - 40} = 10 \text{ metres.}$$

and by equation 23

$$\left\{ 30 \times 5 + 10 \left(\frac{5+x}{2}\right) \right\} \frac{2{,}000}{x} = 60{,}000$$

or since

$$x = \frac{b\,\delta'\,(2\,h + h')}{\delta'\,(2\,h - h')} = x = 7 \text{ metres.}$$

If, once more, we add ten metres to the height, then equation 23

x=25 metres.

and eq. 22 x=10 metres.

The saving thus affected when the dams are of great height becomes simply enormous. The difference, however, between the profile when the dam below C D (Fig. 4) is bounded by right lines, and when bounded by logarithmic curves, such as shown in Fig. 6, is not so marked as in the cases just considered, yet is

* MM. Delocre, Sazilly and De Graeff.

considerable. To take but one case in illustration, a dam of a profile such as Fig. 6 illustrates, with the faces below C D bounded by curves, would require (equation 21) a breadth of base equal to 9.739 metres, the height and thickness at top being as before, 50 and 5 metres respectively, while, as we have just seen, if the faces below C D were right lines, the base would be 10 metres.

Such, in brief, is the relative merit of these three forms of profile, for a dam having nearly its own weight to support. In practice, however, such a dam can, of course, never exist, and it thus becomes necessary to take into consideration the second condition, or that of a dam supporting a charge of water.

PROFILE FOR A DAM RESISTING THE PRESSURE OF WATER.

And here, again, we are to throw aside, at first, all practical considerations, and determine a theoretical profile of equal resistance, one in every part of which the pressure shall not be greater than the limit R′. For this purpose we return to the two equations, deduced some time back, which express the conditions of stability for a dam resisting the thrust of water, and neglecting the signs $>$ and $<$ and the values corresponding to them, take only those corresponding to the sign of $=$. We then have the two following equations :

$$2\left(2-\frac{3u}{l}\right)\frac{P}{\delta' l}=\lambda \quad . \quad . \quad 24.$$

and

$$\tfrac{2}{3}\,\frac{P}{u\delta'}=\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad 25.$$

If we now replace the quantities u, l and P, by their respective values, expressed in functions of the height of the dam, we may readily deduce two equations which, on examination, will show two things.

1°. That the profile offering the least thickness, consistent with the conditions of stability, is one in which the side turned towards the water, has a vertical face, and the side turned from the water, or the outer face of the wall, a concave face.

2°. That as the height increases, the thickness increases less rapidly, so that in a wall constructed with a vertical face on the water side and a curved face on the other side, and so planned that it shall satisfy the conditions of stability as to its base will present an excess of strength for the surplus of height.

Fig. 7 is the profile of a dam of this

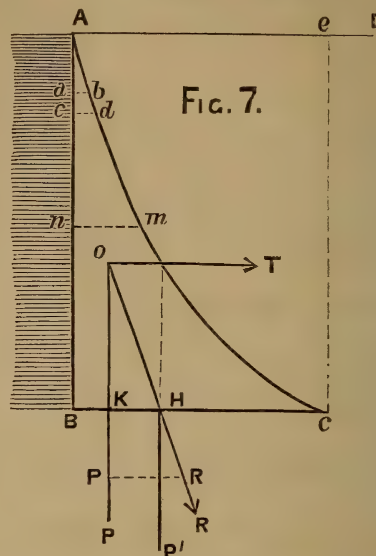


Fig. 7.

description. It will be observed, moreover, that in this form of profile the thickness of the wall at the top is zero. This, of course, in practice is never admissable, inasmuch as it presupposes the water to be at all times in a perfectly quiescent state, and thus makes no allowance for the very considerable force of the waves raised by the wind. It is, therefore, necessary, whatever the profile, to give the dam quite a thickness at the summit, in general, about fifteen feet, is a good width, as it thus enables us to construct a footpath and roadway on the top of the dam, which is quite a convenience.

Before we consider any other modifications, it may be well to determine as nearly as possible the co-ordinates of the concave curve forming the outer face. For this purpose we will take the vertical face A B as the axis of x, and for the axis of y, a perpendicular to this passing through the point A, and call it AD. Anywhere on the curve we will take a point C, and denote its co-ordinates B C $=y$ and C $e=x$; then the relation existing between x and y will give the equation of the curve. Now, as we have already seen, the wall is subject to the action of two forces, the weight of the dam P, which acts vertically downwards

through the centre of gravity and the horizontal thrust T of the water. These two forces produce a resultant R, which cuts the base of the dam in this case at the point H. This resultant, therefore, may be regarded as applied directly to the point H and resolved into two components, H P and H C, respectively, parallel to O P and O T. We have also seen by equation 5 that the horizontal thrust of the water is equal to

$$F' h y = \tfrac{1}{2} h^2 l y \quad . \quad . \quad . \quad 26.$$

Or replacing h by its value, and $l y$ by its value δ, then T, or the horizontal thrust of the water, equals

$$T = \frac{\delta x^2}{2} \quad . \quad . \quad . \quad . \quad 27.$$

And in the same way

$$P = \delta' \int_o^y y\,dx \quad . \quad . \quad . \quad 28.$$

Returning now to equations 24 and 25, we find that the quantity l is equal to y, and that we have therefore to determine the value of u in functions of x and of y. Now u equals H C and H C = K C − K H. The triangles O P R and O K H, moreover, being equiangular triangles are similar, and have their like sides proportional, and

$$KH : PR :: OK : OP$$

or

$$\frac{KH}{PR} = \frac{OK}{OP}$$

or to express the equality in terms of T, x and P,

$$\frac{KH}{T} = \frac{x}{3P} \quad . \quad . \quad . \quad . \quad . \quad 29.$$

Replacing in the 29th equation the values of T and P, as obtained in the 27th and 28th equations, we have :

$$\frac{KH}{\frac{\delta x^2}{2}} = \frac{x}{3\delta' \int_o^y y\,dx} = KH = \frac{\frac{x}{3\delta' \int_o^y y dx}}{\frac{\delta x^2}{2}} .$$

$$= \frac{\delta x^3}{6\delta' \int_o^y y\,dx}$$

Or, for brevity, representing $\frac{\delta}{\delta'}$ by D,

$$KH = \frac{D x^3}{6 \int_o^y y\,dx} \quad . \quad . \quad . \quad 30.$$

This gives us the value of K H in the expression

$$u = KC - KH \quad . \quad . \quad . \quad . \quad 31.$$

But K C is evidently equal to $y -$ B K, in which B K is the distance from the centre of gravity of the surface A B C to the vertical axis of x or A B. This distance is equal to the sum of the moments of the areas such as $a\,b\,c\,d$, or

$$BK \int_o^y y\,dx = \frac{\int_o^y y^2\,dx}{2} \quad \text{or again,}$$

$$BK = \frac{\int_o^y y^2\,dx}{2\int_o^y y\,dx}$$

Hence $KC = y - BK = y - \dfrac{\int_o^y y^2\,dx}{2\int_o^y y\,dx}$

$$= \frac{2y\int_o^y y\,dx - \int_o^y y^2\,dx}{2\int_o^y y\,dx} \quad . \quad . \quad . \quad 32.$$

Substituting in equations 31, the values of K H and K C obtained in equations 30 and 32, we have :

$$u = \frac{2y\int_o^y y\,dx - \int_o^y y^2\,dx}{2\int_o^y y\,dx} - \frac{D x^3}{6\int_o^y y\,dx}$$

Or, reducing to a common denominator, and subtracting,

$$u = \frac{6y\int_o^y y\,dx - 3\int_o^y y^2\,dx - D x^3}{6\int_o^y y\,dx} \quad . \quad 33.$$

Thus, then, we have the value of u in functions of x and y, and substituting this value for u in equation 24, and remembering that $l = y$, we have :

$$\frac{4yP-6uP}{\delta' y^2}=\lambda$$

$$\frac{\dfrac{4\delta' y\int_0^y y\,dx-36y\delta'\int y^2\,dx-18\delta'\int_0^y y^3\,dx-6Dx^3\delta'\int_0^y y\,dx}{6\int_0^y y\,dx}}{\delta' y^2}=\lambda$$

$$\frac{24\delta' y\int_0^y y^2\,dx-36y\delta'\int_0^y y^2\,dx+18\delta'\int_0^y y^3\,dx+6Dx^3\delta'\int_0^y y\,dx}{6\delta' y^2\int_0^y y\,dx}=\lambda$$

$$-12y\delta'\int_0^y y^2\,dx+18\delta'\int_0^y y^3\,dx+6Dx^3\delta'\int y\,dx=6\delta'\lambda y^2\int_0^y y\,dx$$

Dividing both members of the last equation through by $6\delta' y\int_0^y y\,dx$, we shall have, after bringing all terms containing y into the first member,

$$-2y\int_0^y y\,dx+3\int_0^y y\,dx+Dx^3-\lambda y^2=0 \qquad 34.$$

By making the proper substitutions in equation 25,

$$\frac{2\delta'\int_0^y y\,dx}{3\delta'\left\{\dfrac{6y\int_0^y y\,dx-3\int_0^y y^2dx-Dx^3}{6\int_0^y y\,dx}\right\}}=\lambda$$

$$2\delta'\int_0^y y\,dx=\frac{18\delta'\lambda y\int_0^y y\,dx-9\delta'\lambda\int_0^y y^2\,dx-3\delta'\lambda Dx^3}{6\int_0^y y\,dx}$$

$$12\delta'\left(\int_0^y y^2\,dx\right)^2=18\delta'\lambda y\int_0^y y\,dx-9\delta'\lambda\int_0^y y^2\,dx-3\delta'\lambda Dx^3$$

Transposing, after dividing each member by $3\delta'\lambda$, we have:

$$0=4\left(\int_0^y y^2\,dx\right)^2-6\lambda y\int_0^y y\,dx+3\lambda\int_0^y y^2\,dx+\lambda Dx^3 \quad . \quad . \quad . \quad 35.$$

But here a new difficulty presents itself, for no sooner do we attempt to integrate equations 34 and 35, than we see it is quite impossible to perform the integration by any exact method. We may, however, obtain an approximately correct solution by finding the value of y in a series of functions x. Treating equation 34 by this method we obtain, says M. Delocre, for y the value

$$y=a\,x^{\frac{3}{2}}+b\,x^{\frac{5}{2}}+c\,x^{\frac{7}{2}}+d\,x^{\frac{9}{2}}+e\,x^{\frac{11}{2}}+f\,x^{\frac{13}{2}}+\&c. \quad 36.$$

While equation 35 gives:

$$y=a\,x+b\,x^2+c\,x^3+d\,x^4+e\,x^5+f\,x^6+\&c. \quad 37.$$

These equations, as it is quite apparent, are of no earthly value for practical purposes, and we shall, therefore, drop all further consideration of them. Indeed, if it were possible to obtain the equations of the curve A m C, by a short and simple process of integration, a moment's reflection will show that such a profile as that illustrated in Fig. 7 would not be suitable for practical use. For this profile has been calculated on the hypothesis that the dam is *always* to support a head of water equal to its height, and in this case the pressure on any horizontal section as $m\,n$ will, it is quite true, not exceed the limit R. But as it happens that the dam is very likely to be at times empty, the profile must be such that, full or empty, the pressure on any section as $m\,n$ shall not be greater than R. We know that this limit will not be exceeded for the face of the wall bounded by A m C, and it thus remains to consider only the vertical face A B. On reference to the calculations we have made relative to the profile of walls having only their own weight to support, it becomes noticeable that the limit will soon be passed if the wall is slightly raised. Supposing this limit to be reached at the point n, we are forced for the sake of stability to depart from the vertical below this point, to give the water face a swelling or bulging surface, and thus adopt a profile similar to that illustrated in Fig. 8. This profile is supposed to fulfill the conditions that, at any section

as $d\,e$, taken below $m\,n$, the pressure at the point e, the dam being full, will be less than or equal to the limit R, and the dam being empty, the pressure at d re-

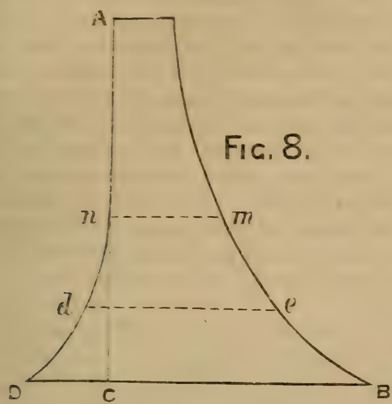


Fig. 8.

sulting from the weight of the structure, will also be less than or equal to the same limit of pressure, R.

This last modification, moreover, is one of no small importance, as it enables us to correct some of the chief errors in which the theoretical consideration has unavoidably led us, and thus to approach nearer to the end in view; the determination of a profile of equal resistance suitable to practical requirements. If the two curves $m\,e\,$B and $n\,d\,$D could be readily obtained by the above formula, the profile of Fig. 8 would answer almost all necessary conditions as to stability and economy; but they cannot. It therefore remains to do the next best thing, and to replace the curved surfaces, by polygonal surfaces of as small sides as possible—in order that they may approach reasonably near to the curves—and then determine the equations of these sides of the polygons; or to adopt a similar method to find the equations of the two curves in question. This we shall now endeavor to do. It is, however, to be remarked that there are two notable instances of the use of the form of profile, shown in Fig. 8; that of the dam at Furens, and that constructed on the Ban, a tributary of the Gier, by M. Mongolfier. Each of these we shall consider later.

OCEAN STEAMSHIP NAVIGATION—ITS PERILS, AND HOW TO AVERT THEM.

By Capt. S. P. Griffin.

Written for Van Nostrand's Magazine.

I.

Seamen believe that the perils of ocean navigation can be very much lessened by correcting some of the evils which are well known to them. Fatal disasters to large passenger steamships are, in many instances, attributed to causes well understood beforehand, and known to have their origin in the continuance of a certain custom on board vessels, and in the unfitness of certain aids to navigation. From amongst the questions relating to the sea that demand attention, I will select two for discussion in this paper; the first one is the danger arising from "Watch and Watch."

From the earliest times to the present, in the internal economy of vessels, both large and small of all nations, in every sea, it has been, and still is the custom, to divide the crew into two watches, working what we designate "watch and watch," that is to say, four hours on and four hours off duty alternately. This plan of work in the days gone by, when vessels were comparatively few and small, and when time was of less value than it is now, apparently did not obstruct, or interfere with the prosperty or the growth of commerce, or the successful navigation of the ocean, but, however well it has subserved a useful purpose in the past, it certainly requires to be changed so far as it is applicable in the present to the mates of ocean going steamships. The exigencies arising from the immense fleets, at all times, in every sea, sailing and steaming in every direction, upon all points of the compass, and

the wonderful increase in the size and speed of first-class passenger steamships render it absolutely neccessary that, with a proper regard for life and property, the deck at all times must be in charge of a man of well ascertained mental and physical abilities. Yet, it is a fact very well known to the initiated, that the custom of "watch and watch," will at times so impair a man's faculties, when thorough efficiency may be most urgently required, as to render him wholly unfit to discharge his important duties; within the experience, and subject to the observation of every one who goes to sea, is the significant reality that a man can not day after day, night after night, in good weather and in bad weather, preserve himself in a condition that qualifies him for every emergency, that inevitably sooner or later, at a critical time, he will be found wanting, and the most serious consequences may become involved in his temporary deficiency, even unto the total loss of the steamship with all on board; hence it is that those ashore hear of the most unaccountable shipwrecks; hence it is that sweet water critics can see the error of judgment, can detect the mistake in navigation, which was the immediate cause of an appalling disaster.

I will describe the duties of a mate at sea, a mate who is intrusted with a watch, he who has charge of the deck of a steamship, freighted with two thousand tons of cargo and a thousand human lives; the steamship runs at a speed of fourteen knots an hour across a crowded sea, upon a dangerous coast, in sunshine or in darkness, in rain or in fog; it is all the same, on she goes with life or death awaiting her, depending to a considerable extent upon the skill, courage and self-possession of this man. His station is upon the forward bridge, within easy call to the man at the wheel, close to the standard compass, and to an engine bell pull. He must not on any account leave it, unless he is regularly relieved. He must keep on his feet, in constant motion, to see that the ship is on her assigned course, that proper sail is carried, that the yards are trimmed, that order is maintained about decks, that the rules concerning lights and fires are obeyed; he must keep a bright lookout ahead and all around, he must listen for unusual sounds, he must be ready to detect unusual smells, he must be unceasing in his vigilance during the period of his watch. After he is relieved at the termination of his watch, he must write in the deck-log the remarks that he thinks are necessary to keep up the narrative of the voyage, he must see that the proper entries are made of barometric and thermometric indications, of the direction and force of the wind, the character of the weather, of the sea and the speed of the ship, he communicates with his relief, and he goes below. This is an outline of the duties, when off watch, or in his "watch below," as it is called; he has to take and work out observations for latitude, for longitude, for variation and deviation, and every day soon after Meridian, he must send in to the captain a carefully prepared report of his "day's work," he must attend quarters for fire and boat exercises, he must be always ready to respond to any sudden call for all hands, he must by his example and his teaching help to inspire confidence, and to maintain discipline.

Let us now enter into a brief examination of the effect this custom of "watch and watch," in its application to mates of steamships. Let us endeavor to understand its operation for good or for evil, as it now prevails upon hundreds of them on duty in every sea. Let us learn if there are not dangers of the deep that are probably never thought of, or even known to exist by those who own the steamships, or by the thousands of passengers who go from port to port in them.

Of the twenty-four hours that compose a day, the mate who stands his "watch and watch," spends twelve of them upon the bridge in charge of the deck. In being called ten minutes before the termination of a watch, so as to be ready to relieve when the bell strikes, and in occupations after it one and a half hours are consumed; at his meals, smoking, and another thing or two, three hours; in observations, day's work, reports, exercises, and what not, one and a half hours more, making in all eighteen hours, thus leaving him only six hours for sleep, to be picked up at intervals between the watches, as best he can, subject to innumerable disturbing influences. Is this amount of rest, and the way of getting

it, enough for a working man anywhere? Is it enough for a man who is exposed to the severe trials of a hard winter in our wild North Atlantic? Do we not see from this that it is beyond the power of human endurance to keep up under it? May we not here begin to find an explanation for some occurrences which in their mysteries have hitherto baffled investigation? I assure you that the custom of "watch and watch," the custom that compels a man to undertake more than he is capable of doing, is the ultimate cause of many of the heart rending disasters which have come to us from the sea.

I will present an every-day case to you, it will be at once recognized by any person who is familiar with the "way things are done aboard ship." It may be in a prolonged gale of wind, in winter, cold, black and gloomy, spray flying everywhere, and freezing where it falls, the decks are slipping with ice, and dangerous from the violent motion of the ship; or it may rain incessantly, or it may be an impenetrable fog. The mate who takes charge of the deck at Meridian, is relieved at 4 P. M., and soon afterwards he goes below; he gets his supper, enjoys his smoke, and at 6 P. M. again takes charge of the deck, for the second dog-watch, which terminates at 8 P. M. As soon as he is relieved he writes up the deck-log, then hurries below, shakes off his dunnage, and by one bell—half past eight—he is turned in and asleep. At ten minutes before midnight he is called for the mid-watch, from 12 to 4 A. M. He has had less than three and a half hours sleep; he went below in wet clothes, he comes on deck in wet clothes, aching and weary from past exertions and insufficient rest. He takes charge, he receives the course, the orders, a statement of the condition of things; he inspects the compass, speaks to the man at the wheel, hails the lookout, cautions the "watch" to stand-by, he shakes himself for warmth, and commences to walk the bridge; he exerts himself to be faithful to his trust, to discharge his responsible duties to the best of his abilities, but, before the termination of his four hours, the time begins to drag wearily along, and at last he becomes conscious of his weakening faculties, aware of the danger that will attend his neglect, and of the accountability to which he will be held, he makes a struggle with himself, and barely succeeds in keeping himself awake; those who keep "watch and watch" in charge of the decks of steamships know all of this well enough; those who have not had the experience, and who doubt the accuracy of the statement, can easily find proof of it, if, in the next passage they are going, they will faithfully stand the watches.

Thus far I have spoken of the mate who has "eight hours in," who goes below after 4 A. M. and turns out again before seven bells—half past seven. Then how much more trying will be the case of the mate who has "eight hours out," he who keeps the watch from 8 P. M. to midnight, and again the watch from 4 A. M. to 8 A. M. Is it not utterly impossible for him to look to windward in a north-east snow storm eight hours of a night? Is it not beyond human endurance to remain in a freezing atmosphere, exposed to the fury of wind and sleet, for that length of time, holding on like grim death against the heavy laboring of the ship and not impair the powers of mind and body, the whole strength of which may be on the instant necessary for the safety of the ship? Most persons who travel by sea, if they trouble themselves to think at all about such things, believe that men are able to do it, that they get hardened to that sort of thing, you know, until at last they do not care the least bit about it. The timid, as they lie stowed away in soft blankets in the warm bunks of the after cabin, would shudder at the frequent narrow risks they run if they did but now of them; they would be overcome with horror at the thought that in the dark and fearful night a weary worn-out mate is straining his imperfect vision to make the dim outline of the rock bound shore, upon which the ship is madly rushing; and he cannot see it, nor can he see the approaching sail, nor the warning rays of a light, nor hear the indistinct roar of breakers, nor the feeble tones of a bell, nor catch the presence of unusual elements on-board nearly so well as when he is in good condition.

A mate does not complain about the dangerous effects produced upon him by the custom of "watch and watch"; he

does not confess his absolute physical inability to thoroughly fulfill all of the requirements of his position, for the alternative as the economy of the ship is managed, and of which he has the greatest dread, is to discharge him with a black mark against his name, and to ship another in his place who will not growl and grumble at his ordinary work. Therefore he keeps his troubles to himself, the evils continue unabated, and it happens at last, that a steamship with her freight of life and riches runs swiftly on to meet a terrible fate without a single timely effort having been made to preserve her.

Hence it may be safely declared that risks of collision, of stranding, of fire, in short all risks pertaining to the sea will be very much lessened if the decks of vessels are always left in charge of intelligent men refreshed by sufficient sleep in comfortable quarters, instead of others completely exhausted by excess of work and prolonged exposure. I conscientiously believe that many of the disasters to ocean going vessels are due to the dangers that I have tried to explain, and to others well known to seamen and such as are within the control of man's capacity as a reformer.

Another word or two upon the dangers arising from the custom of "watch and watch" at sea. It is not only in dark or foggy weather that accidents occur, it is not only in long continued winter gales that ships are lost ; but with the moon and stars shining out in all of their glory, in a beautifully transparent atmosphere, in warm tropical nights, in unruffled water, in a dead calm, vessels run into each other, and others run squarely ashore. The drowsy mate could not see, or seeing could not comprehend, or did not act in time to avert an impending calamity. Instances of this kind are by no means uncommon, and I could easily relate a number of them perfectly well authenticated, but in doing so I might make invidious distinctions, and direct censure where as we have seen there may be mitigating circumstances in the case. But proofs may be found in the marine columns of the daily newspapers by those who know what meaning to put upon the reports.

The reform that is necessary to correct the evils spoken of—the change in a long established custom of the sea, that will oftentimes save ships from destruction, is not in itself a very great one, it is inexpensive, and it can be made at once without any derangement of good order and discipline—it is this : put mates of ocean going steamships in three watches, instead of keeping them in two, give them four hours on and eight hours off watch.

As steamships are manned now, this change can be made without any increase to the compliment allowed to them, therefore there will not be any expense attending it.

Let us inquire into the operation of the three watches rule, and see how it affects the mates. He who takes the watch from M. to 4 P. M. has time for his supper, a smoke and a snooze, before he is called for the first watch. At 8 P. M. he is again on the bridge, where he remains until midnight, he then goes below until 8 A. M., then, once more, he takes charge for the forenoon watch, under this rule he has eight hours in every night, he has time to take proper care of himself, to dry his clothes, to keep his room in order, to be accurate in his day's work, and, far above all else, he is strong in body, clear headed, and self-possessed when he takes charge of the deck—he fully and faithfully performs the duties as officer of the watch.

The second topic that I desire to discuss, in this paper, is the insufficiency of our present sea coast fog-signals as aids to navigation.

When fogs prevail along our coasts, there are in use as a means of warning the adventurous mariner of his proximity to danger, three kinds of instruments for producing sound signals. The first in the order of usefulness is the siren, the next the whistle, and then the bell. The approach to harbors, light-boats and light-houses, on outlying rocks are furnished with one or the other of these. The theory with regard to their use is, that they are capable of emitting sounds of such intensity as will be conveyed to a distance from a given danger, sufficiently great for a vessel to perform any evolution in, that may be at the time essential to her preservation.

Now the important question to be answered as preliminary to the selection of an instrument for producing sound

signals during fogs or in thick rainy weather is this ; what is the least distance to which a vessel may approach a danger and still have reasonable space enough to enable her to extricate herself from it or to avoid it?

A steamship of about four hundred feet in length, that steers well, running at full speed, with the helm hard over, will go around in a circle the diameter of which is about five thousand four hundred feet, or, say nine tenths of a sea mile, in smooth water, without wind in twelve minutes. Let us assume that the swinging of the head, or its motion in azimuth is at a uniform rate, then it will take six minutes in time to head a course directly opposite to the one she was steering, and she will be nine tenths of a mile from the position that she was in when the helm was put hard over, then also it will take three minutes in time to head a course at right angles to the one she was steering, and she will be forty-five hundredths of a mile more in advance of her first position and the same distance to the right or left of it, accordingly as she used the starboard or port helm. In other words under the most favorable circumstances of wind and sea, it will take six minutes to turn and head square away from danger, and the danger must be at least a half mile from where she was when the helm was put over. Under the same favorable circumstances the engines can be stopped and worked back until she gathers steamway in five minutes time and within a distance of a half mile. But the fog signal must be adequate to the case when the steamship is in the most unfavorable circumstances of wind, weather and sea.

Suppose the steamship is running head on to danger, not being aware of its neighborhood, in a rough sea, a strong breeze blowing, all sail set, and a dense fog prevailing, what length of time and what space must she then have to work in? She runs fifteen hundred feet a minute, the sea, the wind and the sails will impede her rapid obedience to the helm, it is known that engines often hang a long time, for a situation like this, before there can be worked astern. Hence we can readily understand that one mile of distance at least is necessary for her safety.

But we must make other allowances, we must adopt a signal that will meet all objections and overcome them. The officer of the watch may not be in a thoroughly wide awake condition, his sense of hearing may be at the moment slightly impaired, he may be slow in reaching conclusions, he certainly will possess some imperfection, and in the peculiar circumstances of the case it may be a perilous one to the ship. For example, his attention is first attracted by a faint and unusual sound that comes to him despite the noises aboard and the swash of the water, it seems like a signal, not knowing that he is near a danger, he listens for a repetition of it, he orders the quarter-master and the look-out also to listen for it,precious time is flying, the steamship is rushing on, when, there it is again, all hear it now—there is no longer any doubt about it, it is right ahead, there is not any time to think ; courage, self-possession, and that spontaneous knowledge of what to do on the instant in extreme peril are necessary, he gives at once the proper order to the man at the helm, who may not comprehend it, or may be startled by its peremptory tone, and puts the wheel the wrong way (this is not by any means an uncommon occurrence), the steamer may be sluggish in her movements, the engineer of the watch may misunderstand the bells, or may not be close to the gear, other circumstances may arise of small importance in themselves, but of vital consequence to the welfare of the ship. Therefore, for safety to a long full powered steamship, running under all sail in a dense fog, head on to a danger, she must receive a warning signal at least two miles from it in distance, and eight minutes in time.

In addition to the Mayor of Sheffield's gifts of a park and almshouses to the town, it was announced at a meeting that Mr. Firth had promised to provide, at a probable cost of some £15,000, a building for the lectures and classes commenced there and elsewhere by the universities. These lectures and classes were well attended by members of the working people and others, and it is understood that Mr. Firth will also subscribe £1,000 towards a scholarship fund if £9,000 are raised by the town for this purpose.

ROADS, STREETS AND PAVEMENTS.*

The announcement of a new work bearing the above title reminds us that standard works well suited to the wants of the present time are not abundant. Especially in the matter of pavements is there sore need of information based on intelligent observation. The numerous failures in city street pavements, within the last few years, have certainly furnished an amount of experience sufficient to be of service as a guide for the future; but to draw a serviceable lesson from such experience requires something more than cursory observation. Only a practiced engineer can properly sum up such results, and draw safe conclusions. Failures in this department of engineering result from a variety of causes; bad material, bad workmanship; an exceptional character in the soil—either of these, may insure such swift destruction, that a verdict of condemnation by an injured community will be so unsparing as to work harm; an excellent material has been often heartily condemned by universal consent, because of a failure that existed in something else.

The name of the author of the present work is a sufficient guaranty that the lessons drawn from recent experiences are well presented, and that the deductions are safe ones.

The treatise is very full upon the subjects of Location and Grades of Country Roads—Earthwork and Transverse Form of Country Roads—Road Coverings—Maintenance and Repairs of Roads—Streets and Street Pavements.

This latter subject is discussed in the fullest manner, and is made to include descriptions of methods of construction of all the pavements that have at any time found favor with the profession or the public.

A chapter on "Hygienic Considerations" is particularly instructive, as the following abstract will prove:

A practical and general recognition of the fact—so well known in the medical profession, and indeed among all ranks of cultured people—that the pavements of a city exert a direct and powerful influence upon the health of its inhabitants, has never been secured. Most people claim simply that a street surface should be durable, smooth without being slippery, and, as a measure of economy, that it shall be durable and easily cleansed; but they go no further.

The advantages of noiselessness are recognized by many upon various grounds; by the large majority as simply conducive to comfort, but by few as conducive to health; while the kind of material used, provided it satisfies the foregoing conditions, and the character of the surface is satisfactory with regard to continuity and impermeability, is far too generally considered to be a matter of small moment.

The hygienic objections to granite, are first its constant noise and din, and second its open joints which collect and retain the surface liquids, and throw off noxious vapors and filthy dust.

In populous towns there is scarcely a moment of silence, night or day. M. Fonssagrives, Professor of Hygiene at Montpelier, says, "I cannot consider such a perpetual vibration of the nerves as harmless even for those who have been born and bred in the midst of the noise. It is certain that it is a very genuine cause of erethisme, and to it must be ascribed the prevalence of nervous temperaments and disease in the large towns. . . I have known a young girl of seventeen years old, suddenly transported from the provinces to a noisy quarter of Paris, show the most alarming symptoms of nervous disorder, which did not subside until she returned to a quieter and less exciting atmosphere. At the periods of a woman's life when she is most subject to nervous maladies, this danger should be most carefully guarded against. And what shall we say of the nerves of children and invalids? If the former are hard to rear in cities which create hysterics at eight years of age, some blame must certainly be laid upon the air they breathe and the moral conditions in which they have been educated; but some part of the evil must be attributed to the influence exercised by noise on these little

* A Practical Treatise on Roads, Streets and Pavements. By Maj.-Gen. Q. A. Gillmore. New York: D. Van Nostrand.

beings, in whose organization the cerebral predominance is the most marked feature. As for invalids, quiet is of the first importance, and the noise in the streets is the cruelest stumbling block in the way of recovery."

Dr. A. M'Lane Hamilton, Assistant Sanitary Inspector of the city of New York, in an official report dated October 19, 1874, says, "A quiet and noiseless street pavement would advance the health of the population to a great extent. The sufferer from nervous diseases would find relief from the noise of empty omnibuses and wagons rumbling or rattling on the rough stones, in the event of a removal of this nuisance. In fact there would be many more sanitary benefits resulting from a change that I can here detail."

It is not deemed necessary to enlarge further upon this point. The writings of eminent medical practitioners are full of testimony to the pernicious influence of street noise and din upon the health of the population, particularly upon invalids and persons with sensitive nerves.

The noisome and noxious exhalations emanating from the putrescent matter, such as horse-dung and urine, collected and held in the joints of stone pavements, constitutes another sanitary objection to their use in populous towns. Exceptions to wood may be taken upon the same, and even upon stronger grounds, for the material itself undergoes inevitable, and, sometimes, even early and rapid decay, in the process of which the poisonous gases resulting from vegetable decomposition are thrown off.

The joints of a block pavement, whether of wood or stone, constitute, after enlargement by wear, fully one-third of its area, and under the average care, the surface of filth exposed to evaporation, covers fully three fourths of the entire street. This foul organic matter, composed largely of the urine and excrement of different animals, is retained in the joints, ruts and gutters, where it undergoes putrefactive fermentation in warm damp weather, and becomes the fruitful source of noxious effluvium. In dry weather this street soil, of which horse-dung is a large ingredient, floats in the atmosphere and penetrates the dwellings in the form of unwholesome dust, irritating to the eyes and poisonous to the organs of respiration. Its damage to furniture, though serious, is unimportant in this connection. In the side gutters and underlying soil the foul matter exists in a more concentrated form, the supply being constantly renewed from the crown of the street, and in many districts, from the filthy surface drainage of backways and alleys peopled by the poorer classes. Is it too much to say that under such circumstances, the infant population and especially the children of poor people in large towns, can only be reared under such predispositions to disease, as will constitutionally render them an easy prey to epidemics in maturer years?

The foregoing are some of the leading hygienic objections to pavements laid in blocks, whether of stone, wood or other material. There are others peculiar to wood alone arising from its decay, its natural porosity, and the spongy character conferred upon it by wear and crushing.

"Impregnation of the wood with mineral matters, to preserve it from decay, may diminish these evils, but nothing as yet tried prevents the fibres being separated, and the absorption of dung and putrescent matter by the wood being continued. The condition of absorbing mere moisture is of itself bad, but when the surface absorbs and retains putrescent matter, such as horse-dung and urine, it is highly noxious. The blocks of pavement with this material are separated by concussion, and are thus rendered permeable to the surface moisture. Mr. Sharp, who examined some blocks taken up for re-pavement, states that he found them, perfectly stained and saturated with wet and urine at the lower portions, while the upper portions were dry. Mr. Elliott, a member of the society, and for many years a deputy of the Common Council of the city of London, has carefully observed the trials of new modes of pavement there, and objects to the wood that it is continuously wet and damp. Wood is porous; it is composed of bundles of fibres. It absorbs and retains wet, foul wet especially. The fibres of the wood are placed vertically, the upper ends whereof fray out, are abraded and become like painters' brush stumps, and are almost per-

manently dirty, or they break like the handle of a chisel which has been struck with an iron hammer or wooden mallet. This fact is beyond all question. Wood is wet or damp, more or less, except during continued very dry weather. Its structure is admirably adapted to receive and hold, and then give off in evaporation, very foul matters, which taint the atmosphere and so far injure health." (Report of P. Le Neve Foster, Secretary, Society for the encouragement of Arts, Manufacture and Commerce: London, 1873.)

Physicians assert that hospital gangrene frequently results from washing the wooden floors of the wards with water, and that on shipboard, new or moist timber, between decks, impairs the health of the sailors. Fatal epidemics at sea have been traced to timber that has become saturated with putrescent matter, or wet with bilge water.

Prof. Fonssagrives, of Paris, says: "The hygienist cannot, moreover, look favorably upon a street covering consisting of a porous substance capable of absorbing organic matter, and by its own decomposition giving rise to noxious miasma, which, proceeding from so large a surface, cannot be regarded as insignificant. I am convinced that a city with a damp climate, paved entirely with wood, would become a city of marsh fevers."

The dust produced by the abrasion and wear of a wooden pavement is regarded by physicians as extremely irritating to the organs of respiration, and to the eyes, and being light in weight, it floats longer in the atmosphere and is carried to a greater distance, than that from any other material in use for street pavements.

The evidence, from a sanitarian point of view, against the use of wood for paving purposes in populous towns, is very strong, but the evils are not developed to the same extent in all localities. Decomposition begins in two or three years in clayey and retentive soils, while it is very considerably retarded and the wood remains habitually dryer and emits less effluvia where the subsoil is sandy and porous.

The most characteristic features and properties of asphalt pavement have been briefly summarized on page—and it is not deemed necessary to repeat or enlarge upon them here. Professor Fonssagrives remarks that, "The absence of dust, the abatement of noise, the omission of joints—permitting a complete impermeability and thus preventing the putrid infection of the subsoil—are among the precious benefits realized by asphalt streets."

Upon hygienic grounds, therefore, asphalt conspicuously stands first, stone second, and wood third, in order of merit.

The correct inference from the foregoing discussion is that no one pavement combines all the qualities most desirable in a street surface. It cannot be sufficiently rough, or sufficiently soft to give the animals a secure foothold, and at the same time possess that smoothness and hardness which is so essential to easy draught. The advantages of open joints and entire freedom from street filth can not exist together, under any reasonably cheap method of cleansing the surface.

A pavement of impermeable blocks, if laid upon a solid foundation, may be constructed and maintained in a water tight condition, by thoroughly caulking the joints with suitable material, leaving the surface sufficiently rough and open to obviate the objection to a continuous monolithic covering, but roughness, combined with the requisite hardness, is incompatible with the freedom from noise attainable with some kinds of acceptable street surface.

In order, therefore, to obtain the best pavement for any given locality a judicious balancing of characteristic merits is generally necessary. The best pavement, so far as we now know, for all the busiest streets of a populous city, where the traffic is dense, heavy and crowded, is one of rectangular, blocks set on a foundation as good as concrete, or as rubble stone filled in with concrete; and the next best is one of Belgian blocks set in the same manner.

The best pavement for streets of ample width, upon which the daily traffic is not crowded, or for streets largely devoted to light traffic or pleasure-driving or lined on either side with residences, is continuous asphalt for all grades not steeper than 1 in 48 or 50.

If the blocks of compressed asphalt

fulfill their present promise, they may be able to replace those of stone upon streets where the latter are now preferable to a sheet of asphalt on account of the steepness of the grade.

It has been urged, as an objection to a concrete foundation, that it is difficult to take up in order to reach the gas and water pipes. This is true only in the sense that good work is not easily taken to pieces. But such a foundation when torn up or deranged from any cause, can readily be restored to its former condition, and the pavement relaid upon it with all its original smoothness, firmness, and stability, conditions which do not obtain with any kind of pavement laid upon a bed of sand or gravel.

Further extracts from this very practical work we reserve for a future time.

REPORTS OF ENGINEERING SOCIETIES.

At the November meeting of the Boston Society of Civil Engineers, a report was made by a Committee, appointed to consider the introduction of the metric system, and what action the Society ought to take respecting it, and the following resolves and orders were adopted:

Resolved, That it is very desirable that the metric system of weights and measures should be generally adopted, and the irregular standards, now in common use, abandoned.

That the Committee on the metric system be hereafter a standing Committee.

That the Standing Committee prepare a memorial to the Congress of the United States on behalf of this Society, praying that honorable body to enact that, after some fixed date, the metric standards in the office of Weights and Measures, at Washington, shall be the sole authorized public standards.

That approximate weights and measures be procured for the Society rooms.

That the State Board of Education and the Boston School Committee be addressed, urging that the instruction be made more thorough by putting the real weights and measures into the hands of the pupils.

That the Committee be instructed to communicate to the U. S. Commission for testing iron and steel, a request on behalf of this Society that their report may be made in terms of the metric as well as the more common standards.

That the Committee be authorized to open correspondence with other Societies with a view to securing united action in petitioning Congress.

That the Secretary be instructed to publish what action the Society has taken on this matter in the principal newspapers and professional periodicals.

Mr. Edward Appleton read an interesting essay on "The Relations of the Railroads to the People, and to the Government of the State and the Nation, what they are and what they should be." Mr. Appleton began with a description of the erroneous ideas of the community when the first charters were granted, and of the systems and rights of the corporation as now constituted. The question of State management of railroads was discussed, and numerous instances of railroads usurping their authority were cited.

Franklin Institute.—At the December meeting, report from the Committee on Science and Arts, in relation to high pressure steam allowed by law on Western Rivers, embodying the following communication, to be signed by the officers and members of the Institute, and sent to both houses of Congress, was read, and on motion of Mr. Orr was adopted:

"To the Honorable, the Senate and House of Representatives of the United States:

"The undersigned, members of the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, held at Philadelphia, in the State of Pennsylvania, respectfully represent that their attention has been directed to an amendment of an Act of Congress, entitled "an Act to provide for the better security of life on vessels propelled in whole or in part by steam," which amendment was approved December 17th, 1872, and which amended Act permits the use of an increased steam pressure in steam boilers of a certain class.

"By their Committee of Science and the Arts, they have examined the subject, and are of the opinion that the said increase of steam pressure allowed by the said amended Act, is not only improper, but prejudicial to the purpose for which the Act was originally enacted.

"At the request of a former Secretary of the Treasury, this Institute made a series of experiments for the purpose of determining the limits of safety, and means of preventing accidents in steam boilers, and made reports and suggestions upon those subjects, with a draft of a bill for the purposes of protection against accidents from steam boilers, which reports were accepted by the Secretary of the Treasury, and suggestions incorporated in various Acts approved by Congress.

"The said reports are likewise referred to as good authority, upon the subject of the strength of materials to be used for steam boilers, both in this country and in Europe, and the results and opinion expressed have been confirmed by the experience of British and French Scientists, and Government Commissions. We find that the increased pressure permitted by the amended Act of December 17th, 1872, will in many instances prove productive of accident, as permitting the use of steam pressures beyond the limits of safety, and we therefore respectfully recommend that so much of the Act referred to as permits of this increase of steam pressure be rescinded, and that a re-enactment be made, which shall restore the law as it stood before it was amended."

IRON AND STEEL NOTES.

The Limit of the Carburation of Iron.—It is impossible to derive a limit of carburation from the variable proportions of carbon entering into commercial iron, combined as it is with manganese, sulphur, etc. To discover whether iron and carbon form a fixed compound, no dependence can be had except on experiments made with compounds containing only iron and carbon, both in a state of purity. Dr. Percy gives 4.4 per cent. as the maximum of carbon able to combine with iron. Karsten gave 5.1 per cent., stating that with this proportion a fixed compound was formed, represented by Fe_4 C. The author could trace no decided difference in combined carbon between white and gray cast iron. The maximum he asserts to be 4.06 per cent., and that any surplus of carbon is in the form of graphite. If an iron containing this quantity solidifies quickly, it is homogeneous, and retains in the solid state the whole of the carbon, whereas, if cooled slowly, it is not homogeneous, there being combined and free carbon, and probably pure iron. Experiments were made at the works of Mr Holtzer, at Unieux, with Swedish iron containing 0.9961 of metal, of which 22 lb. broken in pieces, with the intervals filled with wood charcoal, were melted in a crucible in a Siemens furnace. The metal was run on a cast iron plate; the lower portion of the mass was white, the upper being gray. The following was the result of the analysis:

	Iron.	Combined Carbon.	Graphite.	Total Carbon.
In the mass......	95.90	2.10	2.00	4.10
In the white zone.	95.99	3.585	0.425	4.01
In the gray zone..	95.22	2.67	2.11	4.78

The white zone, in which the proportion of graphite was only 0.004, has nearly the theoretical composition Fe^5C, in which

Iron..................	=	94.90
Carbon	=	4.10
		100.00

The whole of the carbon was, undoubtedly, in combination in the liquid state, and the graphite was formed on the metal cooling. The author, finally, considers there is nothing more curious than the changes in the nature of iron combined with a maximum of carbon produced by the influence of temperature; gray iron transformed into white, by the union of free carbon and free iron; and, reciprocally, white iron changed into gray, by carbon and iron being set at liberty.

RAILWAY NOTES.

Continuous Freight Traffic over Lines of Different Gauges.

Editor Van Nostrand's Engineering Magazine :

Sir—I desire to call your attention to the enclosed slip, which you will see is an extract from your magazine:

"A correspondent, Mr. Joseph P. Noyes, of Binghamton, writes us on the above subject as follows: All, or nearly all freight cars have a stout timber or plank crossing under the body of the car, over the centre of each truck, and projecting an inch or two beyond each side of the car, thus forming four points upon which a loaded car may rest without injury, independent of the trucks.

"Upon these same planks are placed three castings, namely, the pivot and two side bearings.

"What I propose is to have a lifting apparatus, with most of its working parts in a pit under the track, to lift a loaded car bodily off the trucks by the four points above mentioned, run out the trucks of one gauge, and run in trucks of another gauge, and let the car down upon them. The pivots, side bearings, and break chains would have to be of uniform pattern; but in other respects all the existing variety of cars and trucks could be used, and every road would keep its *running gear upon its own road.*

"A 10-horse engine would furnish power to transfer several hundred cars in a day, with switch engines to move them.— *Van Nostrand's Engineering Magazine, March*, 1871."

The precise plan has since been very extensively adopted, but was, so far as I know, original with me, and I presume at that time new to you.

I have never sought any pecuniary reward, but would be glad to have the credit of first making the suggestion, if it belongs to me.

Yours Respectfully,
Joseph P. Noyes.

Binghamton, Nov. 25th, 1875.

The Soudan Railway.—A project which has long dazzled Egypt by its grandeur—the Soudan Railway—is, writes the correspondent of the *Times* at Alexandria, now being taken seriously in hand. The surveys were made long ago; rolling stock, machinery, and other material have already gone forward in large quantities to the interior, and further shipments are constantly arriving at Alexandria. It is a great undertaking, and must ultimately do good service in the development of the interior, but whether the cost, which is estimated at four millions sterling, is justified by the present state of Egyptian finances, is quite another question, and one worth examination. After leaving the first cataract, the traveler, in ascending the Nile, finds that the river makes a great curve to the west. The stream is shut in by rock, and the country through which it passes is chiefly barren desert. It runs like a silver thread through a dreary waste, only broken by an occasional space where are a few huts, a palm grove, and a patch of cultivation. The bed of the river is often rocky, and above the second cataract navigation is very difficult. This great curve is followed by another in the opposite direction, through country of much the same character. The projected railway is for the purpose of abridging these two curves and bringing Egypt into easy communication with the richer provinces that lie beyond them, while the "rivers of Ethiopia" still enrich what was of old the kingdom of the Queen of Sheba. The railway's whole length is to be 550 miles. It starts on the right bank of the

Nile at Wady Halfa, a scene of dreary desolation, where is the second cataract. The line, as projected, soon leaves the river and goes through desert, over rocky mountains, across wild gorges, down which, after the rainy season, rush tropical flood waters with almost irresistible violence, to rejoin the river at Kohé after a run of 150 miles. At Kohé a bridge, approached by an embankment, is to be erected. The portion of the bridge crossing the deep water channel will consist of one central opening of 80 metres, and two side openings of 30 metres, while the remainder of its length will comprise 26 openings of 18 metres each. The iron work of this bridge, like all the rest of the material of the railway, has to go from Alexandria, 300 miles by rail and 600 miles by river. From Kohé to Ambukol, a village at the southern point of the first curve of the river, there is a run of 200 miles through country of much the same character, passing Berber and several smaller towns, the termini on the river of the great caravan routes from Kordofan and Darfur. From Ambukol there is a final run of 150 miles to Shendy, across the Bahinda Desert, uninhabited save by wandering Bedawee tribes, subject at one season to violent dust storms, and at another covered with vast pools, the reservoirs of the tropical rainfall on the impervious slopes of the granite hills. Shendy, a town on the southern edge of the second great curve of the river, is to be the preseut terminus of the railway, and is chosen as being the converging point of the various camel routes for the ports of the Red Sea, for Khartoum and the White Nile district, and for Aboo Kharras and the Blue Nile. Apart from our interest in the construction of this railway, on the ground of its absorption of Egyptian resources (adds the correspondent) it may be important to England for an entirely different reason. It is part of a great plan for an extension of the Egyptian railway sytem, so as to connect the Mediterranean with the southern end of the Red Sea. From Alexandria to Cairo, from Cairo to Rhoda, on the Nile, in Upper Egypt, there is already railway communication; and from Rhoda steamers run on the Nile up to the first cataract. The difficulties the cataract presents to the transit of goods are obviated by a railway of five miles already constructed to the upper level of the river. Hence to Wady Halfa there is again communication by steamer on the Nile, though no regular line of boats is as yet established. When this Soudan railway is completed from Wady to Shendy, the Egyptian Government proposes to continue to Massowah, on the Red Sea. But they are prudent enough to wait until the resources of the country will allow of the outlay required for a railway of about the same length as the one now to be constructed. It is also proposed in the future to complete the railway from Cairo to Assouan and Wady Halfa. Supposing these schemes are ever carried out, there would be direct communication between Alexandria and Massowah, and England would have an alternative route to India for her soldiers. She would avoid the dangers of the Red Sea, and curtail the length of the journey to India by three days. The distance between the various points are about as follows:—Alexandria to Cairo, 130 miles complete rail; Cairo to Rhoda, 180 miles complete rail; Rhoda to Thebes, 268 miles steamer; Thebes to Assouan, 133 miles steamer; Assouan to Philæ, 5 miles complete rail; Philæ to Wady Halfa, 210 miles steamer; Wady Halfa to Shendy, 555 proposed rail; Shendy to Massowah, 500 miles (about).—*Architect.*

ENGINEERING STRUCTURES.

REMARKS ON DEEP BORING AND DEEP MINES. —At a recent meeting of the Geological Society of Glasgow, Mr. D. C. Glen, C. E., submitted a paper on this subject. A series of cores was recently presented to the Society by Mr. H. R. Robson, the President of the Institution of Engineers and Shipbuilders in Scotland, and this led to the preparation of the paper, which was illustrated by maps, sections, tools, &c. The author first spoke of the various modes and machines used in what miners call "boring." The object for making a bore-hole into the crust of the earth is to ascertain where and at what depth the various rocks, minerals, and other substances lie; and the bore is sometimes made for the purpose of getting water or petroleum oil. The method of doing this when the ground is soft through which the bore passes is to use what carpenters call a shell auger, with a cross handle fixed on the upper end, and worked by a sufficient number of men. As the hole gets deeper other lengths of rods are screwed on until the required depth is accomplished. Of course during this process the boring rods and auger have to be withdrawn in order to clear out the recess which is filled with the debris; and so a record is also got of the various formations through which the bore has passed. When rock or other hard substances have to be passed through, a steel chisel-pointed jumper is used, alternately lifted and dropped by the men. In this case the debris has to be taken out of the hole by means of a tube provided with a valve at the lower end; and as the jumper is worked in water the debris is in the form of mud, and as some portions of the upper strata fall into the bore-hole, this mud is not always a correct indication of the substance at the bottom of the bore. The upper part of the bore is often lined with tubing, to keep out water and the softer substances, such as sand and mud, which may have been passed through. When the bore gets deep, and the boring rods too heavy to be lifted by four men, a long tree trunk is used as a lever; and sometimes a steam-engine is required to give the desired percussive or jumping action to the boring rods. In order to save the time lost in withdrawing the rods, the Chinese have a system of using rope instead of rigid rods. But this is objectionable, as it sometimes makes the hole untrue, and should the rope break the heavy chisel is left in the hole. Messrs. Mather & Platt, of Manchester, have made some remarkable borings by means of their ingenious cutter, worked by a flat wire-rope.

An improved method of boring is to have, instead of a chisel jumper, a tube with steel

cutters forming a kind of saw, which, being made to revolve, cuts out a solid core or cylinder of the rock passed through. The cylinder, when brought to the surface, not only gives a true sample of the material, but also indicates the dip or inclination of the strata. This system has been improved upon by Major Beaumont, R. E., whose plan is to fix on the bottom of the boring rod a steel tube, which is faced on the lower end with a number of rough uncrystallized diamonds, named carbonite. Unlike the others described, this boring tool is made to revolve with its face in constant contact with the rock, similar to a drill or cutters in boring iron or other metals. A jet of water is forced down the centre of the hollow boring rods, which keeps the face of the cutters cool, and at the same time carries the debris up to the surface. This drill can be worked at a speed of 250 revolutions per minute, at a pressure of from 400 lbs. to 800 lbs. per square inch. It will then bore granite and the hardest limestones at the rate of 2 in. to 3 in. per minute, sandstone at 4 in., and quartz at 1 in. per minute. The diamond known as carbonite have of late been much used for the cutting or dressing of millstones of French "burr." This is accomplished by having a diamond fixed in a small steel holder, which is worked in a straight slide fixed over the face of the stone. By means of the diamonds, the face of the stone is cut or scratched, so as to make a suitable cutting surface for grinding the flour. Latterly carbonite has been applied to the dressing of freestone ashlar by fixing a number of diamonds in a gun-metal or steel block, and giving them a reciprocating and traversing motion over the face of the stone. It is expected that when this machine is completed it will dress from 600 to 1000 square feet per day, or as much as 100 or 150 men can do in the same time.

Mr. Glen gave following examples of the deep borings and sinkings :—The depth of the Artesian well at Grenelle, near Paris, is 1798 ft., and the bore passes into the gault formation. It yields 476 gallons of water per minute, the water rising to height of 32 ft. above the surface, and the temperature is 81½° Fahr. The well in Trafalgar Square, London, is 393 ft. deep. It descends into the upper chalk. A bore-hole for exploring the coal measures at Creusot, in France, by Herr Kind, is 920 metres, or 3020 English feet, in depth. The deepest bore yet made is in Prussia, at Sperenberg, 23 miles south of Berlin. It has reached the great depth of 4172 ft., and cost £8717, or about 43s. per foot. The deepest coal pit in Scotland is the Victoria Pit, at Nitshill, where the Huslet coal is worked at a depth of 175 fms., or 1050 ft. Monkwearmouth Pit, near Sunderland, was for many years the deepest in England. It is 300 fathoms, or 1800 ft. in depth. Another pit, lying more towards the dip of the coal field, is a few fathoms deeper. The deepest pit in England is now at Dukinfield, near Manchester, belonging to Mr. Astley. Its depth is 408 fms. or 2448 ft. It passes through 22 workable seams of coal. The deepest pits in the world are now in Belgium, in the coal fields lying between Mons, Charleroi, Namur, and Liége. The shafts in several cases are over 750 metres in depth, or 2460 ft.; and one shaft at Gilly, near Charleroi, is 1040 metres deep, or 3411 ft.; and one part has now reached the depth of 3489 ft.—*London Mining Journal.*

ORDNANCE AND NAVAL.

Voorhees's Steering Apparatus.—The object of this invention is to move a ship's rudder easily and quickly, and to have it under as complete control as volition itself. In order to accomplish this object, this invention utilizes both hand and hydraulic or pneumatic power, and also that of steam.

The said invention consists of a winding mechanism and a hydraulic or pneumatic engine operated by said mechanism, or by an ordinary hand steering wheel and ropes, or by both. The winding mechanism itself is operated by power transmitted from a revolving shaft by means of belts, or by the frictional contact of a pinion on said shaft with the pulleys or gear wheels, which form part of said mechanism.

The operation of this winding mechanism is directly controlled by an auxiliary hand steering wheel, and also by the main steering wheel, through the intervention of the hydraulic engine.

The main steering wheel may be used alone to actuate the rudder, as well when connected either to the winding mechanism or to the hydraulic engine, or to both of them, as when disconnected therefrom, and the auxiliary steering wheel may be used in conjunction with either the main wheel, the winding mechanism, the hydraulic engine, or all of them, as is hereinafter fully described.

Beyond providing for the prevention of shocks to the mechanism and helmsman from the violent action of heavy seas upon the rudder by the use of the hydraulic engine above mentioned, the connections of the several moving parts of this machine consist only of ordinary flexible hide or other rope, and chains and rods where desired, so that, whatever shocks may occur, there can be no rigid connections to be broken, jammed, or worn, such as are usually found in steam and other tooth-geared steering mechanisms.

Egerton's Steam Ferry.—Experiments were made with a model of this steam ferry on the lake at the Welsh Harp, Hendon. Mr. Egerton's plan consists in using what may be termed an immense floating platform, propeled by paddlewheels. The structure is composed of three main longitudinal iron cylinders, each 600 feet in length by 26 feet in diameter at the centre, tapering off to a point at each end. The cylinders are divided up transversely into a number of water tight compartments, each properly staged. The cylinders are placed 78 feet apart, and are connected on the tog by means of a series of wrought iron girders, 20 feet deep, thus presenting a platform or ferry 600 feet long by 234 feet wide On the level of the lower flanges of the main girders will be a deck carried on cross girders, the upper deck being carried on the top flanges. The

space between decks will be appropriated to saloons, cabins, engine rooms and other necessary offices, while the upper deck will be appropriated to railway trains, which are to be transported bodily across the Channel from the various railways on either side. The diameters of the cylinders is calculated to be exactly double the height of the highest Channel wave, so that it is expected that no wave will touch the under side of the lower deck. The ends of the tubes are made to taper so as to cleave the water readily and to act as breakwaters to diagonal waves. The whole arrangement will be boxed in between the two decks, and will be made as snug and as comfortable as possible. On each tube, central of its length, will be placed the engines, with a pair of paddlewheels to each engine, steam being taken from two boilers, one being placed in each space intermediately between the tubes. Arrangements are, of course, made for steering the ferry. The model with which the experiments were made at Hendon was 12 feet long by 6 feet wide, and was fitted with boilers and engines arranged as described. The steaming qualities and floating power of the model were demonstrated directly it was placed upon the lake. Unfortunately, however, the experiments had not proceeded far when one of the boilers gave out, and the experiments were brought to a termination. Mr. Egerton's system will, of course, require special landing-places on either side of the Channel, with arrangements for shipping and unshipping the trains. Another proposition of Mr. Egerton's is to construct vessels upon his principle for the transport of cattle from across the Atlantic. For that purpose the central tube would be dispensed with, and several other modifications would be introduced. No doubt Mr. Egerton would succeed in obviating sea-sickness on the Channel by his scheme, although it is one which must involve considerable expense in the new works it will necessitate.—*Iron.*

BOOK NOTICES.

Elements de Geometrie Pratique. Par E. A. Tarnier. Paris: Ganthier-Villars. For sale by D. Van Nostrand. Price $4.00.

All the practical applications of ordinary geometry are either given or suggested by this work. There are 340 pages of closely printed text, and a large finely printed atlas. The author presents the applications in the order of the geometrical text books, and gives numerous illustrations of every principle.

The descriptions of the instruments to be used, and the manner of using them, is very full. The applications are extended to the curves employed in architecture.

An English translation would be an invaluable aid to architectural or mechanical students working without an instructor.

Easy Rules for the Measurement of Earthworks by Means of the Prismoidal Formula. By Ellwood Morris, C. E. Philadelphia. New York: D. Van Nostrand. Price $1.50.

Probably no one subject relating to practice of engineering has received more attention at the hands of writers than this one of Earthwork Computations.

The difference between a bad method and a good one, certainly represents either a large amount of labor, or else a large error in the work.

In the effort to avoid the drudgery of the lengthy but sure methods, many approximate but inaccurate methods have crept into established use. The use of some of the early tables for railway excavation and embankments led to wide departures from accurate estimates; designed only for preliminary work where relative values may be allowed, they are in use for final estimates by some computers.

There are now several good sets of tables by as many different authors, and upon as many different plans of arrangement. Those most in favor with careful engineers present the method of construction and exhibit the limit of possible error.

The most satisfactory of these, to us, is the work before us. In this book the approximate and accurate methods are compared at length, and by aid of elementary geometric demonstration.

How completely this is done, may be seen by the following abstract of the table of contents:

Chapter I. Preliminary Problems.—The Prismoid; Simpson's Rule; Hutton's Prismoidal Rules; Prismoid adapted to Earthwork by MacNeil; The Prismoid in its simplest form computed by several rules; Adaptation of the Prismoidal Formula to Quadrature Cubature, etc.; Application to three round bodies; Equivalence of some important formulas with that for Prismoid.

Chapter II.—First method of computation by mid-section drawn and calculated for area on the basis of Hutton's rule.

Chapter III.—Second method of computation by heights and widths after Simpson's rule.

Chapter IV.—Third method, by means of roots and squares, as modification of the Prismoidal formula.

Chapter V.—Fourth method, regarding the Prismoid as a prism combined with a wedge or pyramid or both.

Chapter VI.—Prof. Gillespie's four rules and a comparison with foregoing third method.

Chapter VII.—Preliminary or hasty estimates made by Simpson's rule for cubature.

Tables for use.

The above abstract, though only a portion of the table of contents, will serve to indicate the scope of the work, and to demonstrate its value to the engineer, the student, or even to the teacher. For the latter, the book presents many excellent suggestions.

Throughout the book there is an abundance of geometrical diagrams.

Pyrology, or Fire-Chemistry. By W. A. Ross. London: E. & F. N. Spon. For sale by Van Nostrand. Price $15.00.

It may, perhaps, be questioned whether chemical reactions produced in the dry way, and at temperatures ranging up to full redness,

have been as thoroughly studied, whether for systematic or for analytical purposes, as the changes and decompositions occurring in the wet way at temperatures not ordinarily exceeding the boiling-point of water. We have, to be sure, pyro-chemical operations on the large scale in abundance. But have all the processes of the metallurgist, limited as they are in their objects, and in the number of bodies operated upon, been found capable of scientific explanation in accordance with re-received theories? We have, on the other hand, in blowpipe analysis, a body of methods by which the presence of most inorganic bodies may be detected with no less ease than precision, But without at all undervaluing the results of such men as Berzelius, Plattner, Forbes, and others, we may still ask whether the standard treatises on the use of the blowpipe include every operation by which the presence of elements or of their compounds "can be discovered in the dry way?" This question Major Ross answers in the negative. Some time ago he communicated certain interesting papers to the "Chemical News," in which he made known a number of novelties which promise, at least, to be useful. Whether these new methods have been tested by mineralogists and chemists, and if so with what result, we are unable to say. We cannot lay our hands upon any memoir, English or foreign, in which they are criticised. Among these novelties, real or imaginary, are "the vesiculation of borax with oxydes dissolved in it, and the corresponding crystals, which form on the surface of the vesicle, laid on cotton in ordinarily moist atmosphere; the vesiculation of boric acid containing alkaline traces, and the detection of potash in them by breathing on the vesicle; the violet color given by cobalt oxyde to phosphoric acid, and the means of thus quantitatively estimating alkalies, which turn blue in certain proportions; spherospheres, or contained balls, formed by cobalt oxyde in boric acid beads; metallic-looking films formed over beds of boric and phosphoric acid held in a good hydro-carbonous pyrocone; decoloration of cobalt with soda by arsenic acid; delicate reactions of oxyde of silver in phosphoric acid, by which it can be detected in most galenas; structure of pyrocones; cobalt solution, reaction given by lime; reactions of chlorine and fluorine; curious reaction of soda in pyrophosphate of lime; separation of substances, especially of metals in alloys, by utilizing their different attractions for heat; the use of aluminium plate as a support; quantitative assay of sulphide of copper by oxyde of lead in phosphoric acid; separation of silica, alumina, ceria, and the alkaline earths, including didymia and lanthana, by means of their behavior in boric acid; quantitative determination of chemical water in clear fused boric acid, by means of a magnesian borate balls; separation of silica and alumina by lime borate balls; separation of didymium and lanthanum borates from ceric oxyde; detection of fluorine, chlorine, and sulphur by means of oxyde of copper in a phosphoric acid bed; detection of phosphoric acid in tourmaline by boric acid; new reaction obtained by a solution of manganese in sulphuric acid; mangano-cobalt solution with the same view; artificial zeolite formed by heating a mixture of potash and pure alumina, for the purpose of detecting alumina or lime, or caustic alkali; yellow and brown oxydes of thallium obtained on aluminium plate from the metal; detection of sulphuric acid by the effervescence caused by adding a drop of water to a natural sulphate (as gypsum) which has been fused with soda on aluminium plate; decrepitation observed to be peculiar to crystalline forms; solution and separation of silica by boiling with boric or phosphoric acid dissolved in water; sublimation of gold, silver, and other metals by fusing them in the oxydizing flame with a minute proportion of lead or charcoal over aluminium; the curious crystallization of soda combined with a small proportion of lime; the determination of the mineral constituents of animal or vegetal organisms by burning the latter on a bead of boric acid." It is utterly out of our power to judge these novelties in the only fair manner; that is, by working through them one by one and deciding in how far the author's observations and methods can be actually verified. But this is a task which ought not to be neglected, and we are strongly of opinion that, whatever might be the result, such an undertaking would be well worth the while of any student endowed with the needful leisure, skill, and patience. Even if we suppose, for argument sake which is extremely improbable, that the author should be found mistaken in every instance, the detection of his errors could not fail to be profoundly instructive.

We have no great respect for writers who take up some subject in an unsystematic way, and after a desultory course of reading think themselves entitled to lay down the law and to point out the supposed mistakes of received authorities. Of such men, and of their productions, every page of which testifies to the want of all fundamental intellectual discipline, every scientific critic is absolutely sick. They swarm upon us like a new plague of flies. But Major Ross belongs to a totally different category. He is no "paper-philosopher," but an earnest, careful, persevering worker, possessed of a fruitful and suggestive mind; and his conclusions, therefore, however unexpected, cannot be without value. We strongly recommend his work to the attention of chemists and mineralogists in the belief that they will find it both interesting and useful. —*Quarterly Journal of Science*

CARPENTRY AND JOINERY FOR AMATEURS; containing a full description of the various tools required; with Practical Instruction for their Use. By the Author of "Turning for Amateurs," &c. London: The "Bazaar" Office.

This book contains more, in one sense, than its unpretending title page claims for it; as it gives very extended and full information not only as to the use of tools, but as to the principles and methods to be followed in the principal classes of operations included in joiner's work; perhaps in some instances going beyond

what amateur workers are likely to undertake, though this does not make the book the less useful. The illustrations of tools and of the various ways of putting wood together are very well and clearly executed; and the writing generally is marked by clearness and terseness, without omitting anything essential. The writer looks at his subject from more than a merely practical point of view, as his remarks in regard to veneering show. In giving directions for this process, he comments on the difficulties in regard to fitting veneer to curved surfaces, for which special holdfast or "cauls" have to be made, for keeping the veneer in its place until it binds properly; "and hence it is, among other causes, that we see so many repetitions of the same pattern issued from any particular shop, and such unwillingness to depart from them. There is far more freedom in this respect when veneer is not intended to be used." Outsiders, as he says, are not acquainted with the complication of the process of veneering in case of articles that present any but the simplest forms; and any common sense person reading for the first time even the brief instructions and description of the process given here for the use of amateurs, would probably feel a degree of wonder at the trouble that is taken to get over the difficulties which oppose the practice of a sham method, half the care and labor bestowed upon which would suffice to produce some really good and honest work of a high class, in perfectly good though less costly material than that generally used for veneering. In general, throughout the book, the best way of doing everything, in regard to the use of the material, is well brought out; the exception, as usual, being in the case where some form supposed by force of habit and fashion to be ornamental or artistic is to be illustrated, and then we have such things as the claw leg for a pillar table (p. 121), or the spiral or scroll leg (p. 123); forms not only wretched in themselves as regards appearance, but such as no sensible workman in wood, if not under the influence of the demon "taste," would ever think of adopting. This is always the case, we find, in these practical books, whenever the writers travel out of the line of the practical into what they regard as the ornamental, in which they are governed, generally, by mere habit and bad precedent, without any consideration as to whether the forms portrayed really are consonant with the best way of working the material, or with the purpose for which the object is designed.—*Builder.*

British Manufacturing Industries. By G. Phillips Bevan. London: Stanford. For sale by D. Van Nostrand. Price $1.75 per vol.

When we received the two volumes of this series which are now before us, we naturally turned to the preface to see what could be the object of their publication. The names of the writers on the different subjects are sufficient guarantee that the matter is interesting, but what is the *raison d'etre* of the "series"? Its object is, we are told, to bring into one focus the leading features and present position of the most important industries of the kingdom, so as to enable the general reader to comprehend the enormous development that has taken place within the last twenty or thirty years. The books "do not lay claim to being a technical guide to each industry;" then why were they written? The general reader will glance over them and throw them aside, and it is acknowledged that those interested in the trades described will not derive much knowledge from their perusal. However, that is for the consideration of the publisher and the public. The matter is well written, and so far as we have examined it, is trustworthy. Mr. Arnoux writes on "Pottery," Professor Barff on "Glass Silicates," and Mr. J. H. Pollen on "Furniture and Woodwork." These essays are very well as far as they go, but we doubt their utility. The information is rarely of practical value, while often it is of an indefinite nature, as, for instance, in Professor Barff's essay on so interesting a subject as looking-glasses. He describes the method of covering the sheet of tinfoil with mercury, and then says "the glass plate to be silvered, having been made perfectly clean, is *floated* upon the surface of the quicksilver—an operation requiring care—and is then covered all over with weights," &c. This term "floating" is deceptive, and does not instruct the reader in the actual method, which, as our readers are aware, consists in sliding the piece of glass on to the tinfoil in such a manner that the surface of the mercury is entirely removed—a most essential detail of the mercury process of silvering looking-glasses. It may be said that this is a technicality, but when a writer goes so far into his subject as to describe the process of floating, he might just as well describe it accurately. In another volume we find an essay on "Iron and Steel," by Mattieu Williams, which we need scarcely say is good as far as it was possible for its author to make it so in the space at his disposal. "Copper Smelting," by J. A. Phillips, and "Brass Founding," by W. Graham, are also well treated, but are of little use to the practical worker or the amateur. Indeed, each of the subjects requires a volume to itself, though of course if there is a reading public interested in the perusal of these descriptions of our industries, the *raison d'etre* of the present volumes is established. Certainly the editor has selected his authors well, for D. K. Clarke writes on "Railways," R. Sabine on "Telegraphs," Dr. Rimbault on "Musical Instruments," and Professor W. W. Smyth on "Collieries"—sufficient guarantees that the best that could be done in the space has been done.—*English Mechanic.*

Sketches of Artistic Furniture. By Collinson & Lock. London. For sale by Van Nostrand. Price $5.25.

This is just what its title signifies, a collection of artistic designs for furniture. It is a neat folio, and the designs are good. They include the articles of constant use as well as those that are professedly ornamental only.

This book will doubtless find a use with many, to whom a few years since it would have been useless.

Furniture dealers are now prepared for orders from designs, and the custom of thus furnishing houses and apartments seem likely to prevail widely.

DESCRIPTION OF THE INTERNATIONAL BRIDGE OVER THE NIAGARA RIVER, NEAR BUFFALO. Toronto: Copp, Clark & Co. For sale by Van Nostrand. Price $9.00.

This is a fine quarto of 65 pages, and illustrated with twenty-one plates, most of them of large size.

The text gives in separate chapters the history of the enterprise: The Characteristics of the River; The Foundations; The Masonry; The Superstructure; Ice.

The history of the progress of any great engineering work, if it include descriptions in detail of the technical operations, is a valuable addition to professional literature.

The present work seems to be wanting in no respect the qualities that entitle it to such a place in our scientific libraries.

MISCELLANEOUS.

ON THE SINKING OF A PAIR OF IRON SHAFTS FOR AN EXPERIMENTAL AMBER MINE.—The supply of amber in commerce is mainly derived from the district of Samland, near Konisberg, in Eastern Prussia, where it occurs in a deposit locally called "blue earth," in a brown coal formation of the Tertiary age. Until lately amber was got chiefly by dredging and by collecting the fragments thrown up during heavy gales on to the sea-coast, or by shallow, irregular diggings a short distance inland. Recent geological researches having proved the continuity of the amber-bearing beds, the Prussian Government considered it desirable to start an experimental mine, to determine the conditions upon which concessions might be granted to private individuals, the right of working amber being one of the Crown privileges in Prussia.

The locality selected is at Nortyken, in Samland, where the amber-bearing bed has been found by boring to a depth of 140 feet. The section is as follows:

Hard blue earth, without amber.	Feet 2
Blue earth, rich in amber	4.9
Barren earth, no amber............	1

The level of the bed is 18.7 below the level of the Baltic. The overlying strata, 140 ft. thick, consists of sands and clays belonging to the brown coal formation. The works planned for laying out the mine consist of two winding shafts, two bore-holes for pumping, and the necessary engines and boilers. As a large quantity of water was to be looked for in sinking, it was decided to bore the shafts and line them with wrought iron tubes. The depth of both shafts is about 147 ft. and the distance between them is 73.8 ft.

The boring head was a horizontal bar, carrying four chisels for cutting into the bottom of the hole, and two at each end radially for describing the outer curve of the shafts. It weighed about 17 cwt. The boring rods of wrought-iron were of two sizes, one being an inch square, used in boring percussively; and the other 2 inches square, used when a twisting strain was applied.

The sand-pumps, or shells, for removing the detritus produced in the boring, were of two sizes; the larger being 3.1 ft., and the smaller 2.1 ft. in diameter, the length in each case being 6.4 ft. They were wrought iron cylinders with clack valves at the bottom, but the suspension was so arranged that when brought full to the surface they could be emptied by being tipped like a bucket, without the necessity of being detached from the rods. The iron tubes lining the shafts are of best boiler plate, 0.8 in. thick, and 4.6 ft. internal diameter, in lengths of 4 ft., joined by internal rings of the same thickness and riveted. The tube is further strengthened internally by three longitudinal strips of iron of the same thickness. The bottom length of tube is of double thickness, and terminates in a cutting shoe of triangular section. The total weights of the lining tubes are 44 tons for shaft No. 1, and 45.6 tons for shaft no 2, or rather more than 1 ton per lineal yard.

The sinking of the tubes was effected by pressure applied by screws. A cast-iron ring grooved underneath to fit the tube, and having four perforated lugs through which the pressure screws passed, was placed on the top of the tube, and the pressure was applied to the nuts by men working spanners. The lower ends of the screws were attached to a fixed point or abutment formed by a timber platform loaded with cast-iron; four screws were placed at equal distances around the circumference of the tube. The spanners were slung by tackles for convenience of manipulation, and from four to five men worked at each, so that from 16 to 20 men were employed in pressing down the cylinder. The amonnt of material displaced for each length of tube was about 53 cubic feet, which was removed in four or five fillings of the larger-sized shell in about six working hours. The sinking of the tube occupied about four hours, so that one complete length of the shaft tube was sunk and a fresh length slung and adjusted for riveting in each shift of 12 hours. From the sandy nature of the ground little actual boring was required, the use of the chisels being confined to cutting through beds of shale. The work was done in day and night shifts of 12 hours, with an average of 27 men. No. 1 shaft was completed in 121 shifts, and No. 2 in 106 shifts, including both boring and riveting. The latter operation occupied rather more than half the time. The total cost of the two shafts was as follows:

Wrought-iron lining tubes..	£4093
Boring Plant..............	1259
Carriage..................	720
Labor for riveting and sinking..................	715=£6787

The water level during the sinking was constant at 32.8 ft. below the surface, the shaft being about 46 ft. above the bottom of the valley.

—H. KUHN, Zeitschrift fur das Berg-Hutten-und Salienenwesen.—H. B., *in Proceedings of London Institution of Civil Engineers.*

VAN NOSTRAND'S
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THE PROFILES OF HIGH MASONRY DAMS.

By JOHN B. McMASTER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

II.

As this form of profile, therefore, has been illustrated, and its economy, durability and strength fully tested in the case of the dam at Furens, and in that over the Ban, we shall now undertake its investigation, and determine a series of formulæ for the calculation of the logarithmic curves forming the inner and outer face of the dam, and, finally, the establishment of a *profile type* suitable for dams of various heights. Our investigation, moreover, is to be based on the practical experience of MM. Graeff and Mongolfier, in the construction of the dams of Furens and over the Ban, and the brief but thorough report of Professor Rankine on this form of profile, to many parts of which we are greatly indebted.

In the first place, as to the limit of pressure, two questions naturally present themselves: first, what shall be the greatest limit of pressure we may with safety assume? and secondly, is the same limit to be adopted for the inner as for the outer face of the structure? As regards the first question, it becomes evident at a glance that the limit R′, to which any point in the dam may be subjected without thereby endangering stability, will depend, to no small extent, on the nature of the stone, cement, or mortar used. Yet here, as in other cases where masonry is used, it is possible to assign a general limit, based upon practical experience, which should not in any case be overstepped, and if possible rarely equaled. In the two dams to which we have above alluded, the limit of the pressure was taken at 6 kilogrammes per square centimetre, or 60,000 kilogrammes to the square metre, or taking the kilogramme as equal to 2.20485 pounds, 132.291 lbs. per square metre, which in turn is equal to 1.1954 square yards. In Spain, however, and indeed, we believe in some instances in France, the limit of pressure has been taken so high as 14 kilogrammes per centimetre, and the dam found to stand well, but in the majority of cases at from 6 k. to 8.50k., generally at 6 k., per square centimetre. We may express this pressure in another form much more familiar to English engineers, and take as the limit of pressure for each square foot or square yard, a column of masonry having that area for a base and a height of 160 feet. This is also based on experience, as it is well known that good rubble masonry will, when laid in strong hydraulic cement, bear with safety the pressure arising from the weight of a

column 160 feet in height. Taking, again, the density of masonry as double that of water, this pressure would be equaled by a water column 320 feet high, or a pressure per square foot of 20,000 pounds.

The next question as to whether the limit of pressure should be the same, both for the inner and outer face of the dam, seems to be viewed very differently by different engineers, and to admit in practice of a variety of solutions. In the dams constructed by M. Graeff and M. Mongolfier, and in the theoretical profiles offered by M. de Sazilly and M. Delocre, the same limit of pressure was adopted for each face, and the discussion of the formulæ thus much simplified. Yet there seems to be much ground for departing from this observance and for adopting two limits, one for the outer and one for the inner face, provided that the dam has such a logarithmic curve of profile as that we are considering. It is evident that the vertical pressure along these two faces is, at different times, unequal; that when the water is of great depth behind the dam the outer face is more severely strained than the inner, and that when the water is very low, and the dam has little more than its own weight to resist, directly the opposite result takes place and the severest strain is found along the inner face. It is likewise evident that the pressure at any point along these faces must, in all cases, be of necessity in the direction of the tangent to the surface at that place. If the face is vertical, the quantity we derive by the usual equations is the true vertical pressure, or rather the *entire* pressure. But when the surface slopes off from the vertical, as it does in this case, the pressure is in the direction of the tangent, is *inclined* to the vertical, and the quantity which the formula gives us is not the entire pressure, but only its *vertical* component. The *whole* or *real* pressure of course, exceeds this vertical component, by a ratio which grows greater and greater as we pass down the face of the dam to parts where the batter, or slope of the face, departs more and more largely from the vertical. But the outer face has a very much greater batter than the inner, and the water being high, is subjected to a much greater strain, so that, to equalize matters, and not allow the outer face, when the dam is full, to suffer a greater strain than the inner face when the dam is empty, it becomes most expedient to take a lower limit for the vertical pressure at the outer than we do for the intensity of the vertical pressure at the inner face.

Adopting this view, it remains to fix these two limits of vertical pressure. On the inner face, it is clear, where the slope deviates so very little from the vertical that, for all intents and purposes, it may be safely neglected, we may take that we have already fixed upon, namely, the weight of a column of masonry 160 feet high. For the outer face, we may take a pressure whose vertical component is represented by the weight of a masonry column 120 feet high, a pressure which has been deduced from the practical examples of M. Graeff.

The next matter to be taken into account is that of tension, which must, so far as possible, be avoided in every portion of the dam. And this brings us to the consideration of the "lines of resistance," of which in structures subjected to such varying pressure, there are of necessity two; one for the condition that the dam or reservoir is full of water, and one for the condition that it is empty. As in the case of earth retaining walls and buttresses, these are lines passing through the centre of gravity of each course of masonry, and may, when the faces of the dam are rectilinear, be found by any of the formulæ used for such purposes. They bear, therefore, intimate relations to the stability of the dam, the latter decreasing as they depart from the centre of thickness and near the faces. They also bear relation to the tension, and in order that the latter may not become appreciable in any part of the structure, they must not deviate at any point from the line passing through the centres of thickness, either outward when the dam is full, or inward when empty, by a distance greater than one-sixth of the thickness at that point.

With these conditions in view, we now pass to the consideration of the profile.

PROFILE TYPE FOR DAMS HAVING CURVES FOR BOUNDING FACES.

Let Fig. 9 represent the profile of a dam bound by logarithmic curves, the various equations relative to which we

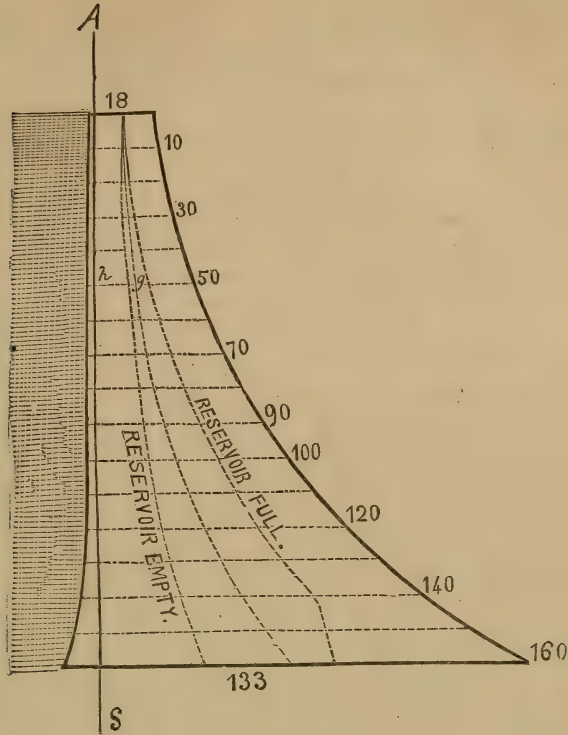


FIG. 9.

wish to find. Let the vertical line A S represent the asymptote of the curves, and taking C as the origin of co-ordinates represent by x all horizontal, and by y all vertical measurements, by b the breadth or thickness of the dam at E D, and by b' the breadth at any other place lower down. Also let s represent the sub-tangent common to the two curves, and represented in the figure by that part of the asymptote contained between F and G. As to the lines of resistance let their deviation from the middle of the thickness when the dam is full and empty be expressed by the letters r and r' respectively, and by R and R' denote the limits of pressure; the first for the outer, the second for the inner face.

Now, adopting Professor Rankine's method of procedure, it becomes evident that if the thickness across the top be expressed by b, then the thickness at any other portion of the dam lower down, and at a distance y below the top, will be expressed by the equation

$$b'=b.e^{\frac{y}{s}} \quad . \quad . \quad . \quad . \quad . \quad 38.$$

in which e is the modulus of the common system of logarithms, or 0.434294. To apply this equation therefore to practice, it is necessary to know the value of the sub-tangent, the thickness across the top and the vertical distances of different points on the face of the dam below the axis of X. These latter points are, of course, assumed at random, and have in the present case been taken five feet apart. As to the thickness at the top it has been taken at eighteen feet. In the dams already alluded to (those of MM. Sazilly and Mongolfier) with the height of 50 and 42 metres respectively, and a limit of pressure of 60,000 kilogrammes per square metre, the thickness across the top is, in the former, five, and in latter, five and seven-tenths metres, which, expressed in feet, gives for the one 16.4 and for the other 18.6 feet. But in this instance we have slightly enlarged on the thicknesses used by those engineers, in order to produce a profile suited for a dam required to resist not only the thrust of water, but also that of ice when carried down by spring freshets.

The determination of the sub-tangent s is not so obvious, but may be found by giving to the exponent $\frac{y}{s}$ of e an approximate value of $\frac{3}{8}$, which substituted in the formula (to be found below) of Prof. Rankine, gives a corrected value of $\frac{11}{8}$, and a sub-tangent equal to 80 feet.

If, then, adopting this breadth of 18 feet on top, we desire to find that at a point thirty feet below, we may write equation:

$$b' = \log.\, b + 0.434294 \times \frac{30}{80} \quad . \quad 39.$$

$$= 1.255273 + 0.162858 = 26.19 \text{ feet},$$

which is to be measured off in such wise that thirteen-fourteenths of it shall lie on the down stream or outer side of the asymptote, and the remaining one-fourteenth on the up stream or inner side. Taking other values for y and proceeding in precisely the same way, we thus obtain any desired number of points through which must pass the logarithmic curves that form the faces of the dam. This done and the curve drawn, the next step is to determine the lines of resistance when the dam is full and when it is empty. To begin with the latter case, the dam being empty, the deviation of the line of resistance from the middle of the thickness will evidently be *inward* or towards the up stream side of the dam. This deviation we have expressed by the letter r', and if we wish to find its value for a horizontal section of the dam taken 50 feet below the top, we proceed as follows. Let z denote the distance hg or the deviation of the centre line of the thickness outward from the axis A S, and by z' the deviation of the same line from the same axis at the top of the dam. Referring to Fig. 9, the distance we wish to find is that denoted by the letters mh, which is evidently equal to $gh - gk$, divided by 2, or

$$r' = \frac{z - z'}{2} \quad . \quad . \quad . \quad . \quad 40.$$

Because the dam having only its own weight to carry, the line of resistance must cut the line gh in a point vertically below the centre of gravity of that part of the structure above gh.

The thickness of the dam where y is fifty feet is found from equation 39 to be 33.63 feet; the centre of thickness 16.81, and the value of z or the deviation of this centre from the axis A S is 14.41 feet. That of z' or the deviation at the summit of the dam is 7.72 feet, from which it follows that (eq. 40) $r' =$ 3.35 feet. It is in this way that the values of r', given below in Table A, have been calculated.

It is next necessary to determine an equation from which to find the values of r, or the amount by which the line of resistance deviates outward from the centre of thickness when the dam is full. It is evident this deviation will depend upon three things, the moment of the horizontal thrust of the water, above the section at which we wish to find r, the weight of the dam above this same section, and the amount by which the line of resistance is moved *inward* when the dam has only its own weight to carry, so that if we divide the moment of the thrust by the weight, and *subtract* the quantity r', we shall at once have the value of r. The thrust of the water above any horizontal section of the dam is, as we have already seen by equation 2, $\frac{y^2}{2} \times 62.5$ lbs., and the moment is, therefore, $\frac{y^2}{2} \times 62.5 \times \frac{y}{3} = \frac{y^3}{6}$ 62.5 lbs., or, what is the same thing, if we express by w the ratio in which the masonry is heavier than the water, and take, as is usual, this ratio as 2, we shall have for the moment (expressed by m) of the horizontal thrust of the water,

$$m = \frac{y^3}{6\,w} = \frac{y^3}{12} \quad . \quad . \quad . \quad . \quad 41.$$

The weight of any lineal unit of the dam above the section may be found most simply by the calculus. Thus giving to y and b the same signification as before, and taking the weight of a cubic unit of masonry as the unit of weight, the weight of each unit of length of the wall above the section is expressed by

$$W = \int_0^y b'\,dy \quad . \quad . \quad . \quad 42.$$

Integrating this between the limits y and o, and remembering that $b' = b\,e^{\frac{y}{s}}$ we have:

$$W = s\,b\left(e^{\frac{y}{s}}-1\right) = s\left(b\,.\,e^{\frac{y}{s}}-b\right)$$
$$= s\,(b'-b) \quad . \quad . \quad . \quad 43.$$

For r, therefore, we have:

$$r+r'=\frac{m}{W}$$

$$r=\frac{m}{W}-r'=\frac{\frac{y^3}{12}}{s\,(b'-b)}-r'$$

or
$$r=\frac{y^3}{12\,s\,(b'-b)}-\frac{z-z'}{2} \quad . \quad 44.$$

This equation gives for the value of r at the distance fifty feet below the top, the quantity 5.18 feet, which, as it falls below one-sixth of the thickness at this point, we are justified in considering the deviation as not too great to be perfectly consistent with stability.

But, to make assurance doubly sure, we may apply a final test as to stability, by calculating the amount of vertical pressure at various points along both the inner and outer faces, and comparing the results with the limit of pressure, which, it will be remembered, has been fixed for the inner face at weight of a column of masonry 160 feet in height, and for the outer face at that of a column 120 feet high. This matter we have already considered at length, and have deduced two equations, 13 and 14, which as they are perfectly suited to the present case, we shall not delay to deduce others, but alter them to suit the notation of Fig. 9. Thus altered they are, calling p and p' the pressures at the outer and inner face respectively, and P and P′ the limit at these same faces—

$$\left.\begin{aligned} p&=2\left(2-\frac{3\,u}{b'}\right)\frac{W}{b'}=\text{ or }<P \\ \text{and}\quad p&=\frac{2\,W}{3\,u}=\text{ or }<P \end{aligned}\right\} \quad 45.$$

While for p' we have two others precisely similar, with the exception that P in equation 45 is changed to P′. It may, perhaps, be well to again remark that the first or second value of p in equation 45 is to be used according as the value of u is greater or less than one-third of the thickness, and that in all such profiles as that of Fig. 9, the quantity u denotes the distance from *the outer face* to the *line of resistance when the dam supports a charge of water*, and from the *inner face* to the *line of resistance when the dam or reservoir is empty.* To illustrate by one example, let it be required to find the vertical pressure at the point C, on the outer face of the dam (Fig. 9), situated fifty feet below the top. By referring to Table A, we see that b' is equal to 33.63 feet, that the outward deviation of the line of resistance is 4.98 feet, and that u must therefore be 11.83 feet. The quantity $W=s\,(b'-b)$ is 1250.4. Since u is here greater than $\frac{b'}{3}=11.21$, we use the first of equation 45, and, making the substitution of values, we have:

$$p=2\left(2-\frac{35.49}{33.63}\right)\frac{1250.4}{33.63}=70.555$$

Thus showing that the pressure is but a little more than half the limiting pressure. Precisely the same operation repeated, with u equal to 13.46 feet, will give the amount of vertical pressure at the inner face at a point fifty feet below the top, the dam supporting only its own weight. This pressure is thus found to be equal to a column of masonry 59.4 feet in height.

The area of the entire profile or of any portion of it, included between two horizontal sections, may be found by taking the difference between the thickness of the dam at these two sections, and multiplying the difference by the subtangent. For it is evident from the figure that, if b equals the thickness of a point y feet from the top, then this thickness multiplied by the differential of the height and integrated between the limits y and zero, is the area, and this expression $\int_0^y b'\,dy$ when integrated, remembering that b' is equal to $b\,e^{\frac{y}{s}}$ gives $s\,b\,e^{\frac{y}{s}}-s\,b$, or replacing $b\,e^{\frac{y}{s}}$ by b', the expression for the area becomes $s\,(b'-b)$. In the notation we have used b means the thickness of the dam across the top, but in calculating the area of any portion of the profile not bounded by the top thickness, the quantity b is to be understood to mean the smaller of the two thicknesses which bound the area. That is to say, if we wish to find the area of that portion of the profile

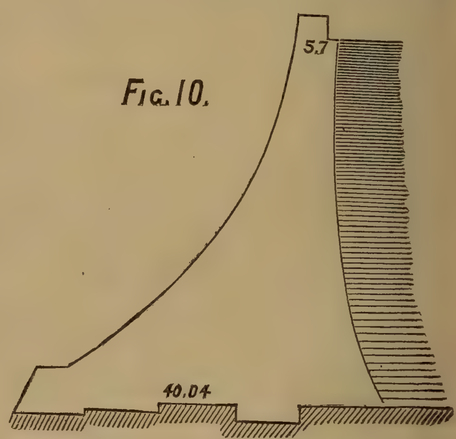
included between horizontal sections taken at thirty and eighty feet below the top, b represents the thickness at the former section, and we have 80 (48.93 $-26.19) = 1819.2$ square feet. Having the area, the solid contents and weight for any length of the dam are of course readily found. The areas for sixteen different sections of the profile, each having the top of the dam for one side, have been calculated in this way, and will be found entered in the last column of Table A. The first column of this table gives the distances in feet of the sections estimated from the top downwards, the second the thickness of the dam at these sections, the third the deviation of the line of resistance outward when the reservoir is full, the fourth the deviation inward when empty, and the last the areas.

TABLE A.

		r'	r	Area sq. feet.
0	18.00	0	0	°
10	20.40	.51	.18	192.00
20	23.10	1.09	.54	408.00
30	26.19	1.75	1.68	655.20
40	29.68	2.52	3.18	934.40
50	33.68	3.35	5.18	1254.40
60	38.10	4.53	6.66	1608.00
70	43.17	5.39	8.79	2013.60
80	48.93	6.62	10.52	2474.40
90	54.18	7.75	12.95	2894.40
100	62.97	9.63	13.53	3597.60
110	71.18	11.39	15.02	4254.40
120	81.79	13.62	14.59	5103.20
130	91.39	15.72	15.46	5871.20
140	103.60	18.34	15.05	6848.80
150	115.00	20.78	15.46	7440.00
160	133.00	24.64	12.46	9200.00

It is perhaps unnecessary to call attention to the fact, that this form of profile has been calculated with a view to its serving as a *profile type* for dams of any height, great or small, whose faces are logarithmic curves. For a dam, then, of which the height is thirty feet, that portion of Fig 9, above the line marked 30, is the proper profile: for one eighty feet in height, that portion above the line marked 80, and so for each succeeding section. It presents again many strong points not found in dams of the usual rectilinear profile, which are especially deserving of consideration when damming a river or valley of great breath and depth. Of these not the least is its economy of material, which, as we shall hereafter see, is very great as compared with that of stepped or sloping profiles; while the curves of the two faces are so gradual that no great mechanical difficulty can arise in cutting the facings. Another matter, which, in the dams of Furens and the Ban was not taken into account, that of tension, has here been considered and the profile so determined that when the reservoir is full the tension on the outer face shall not at any point be greater than it is on the inner face when empty.

The profile of the Furens dam is given in Fig. 10, and that constructed on the



Ban, a tributary of the Gier, in Fig. 11.

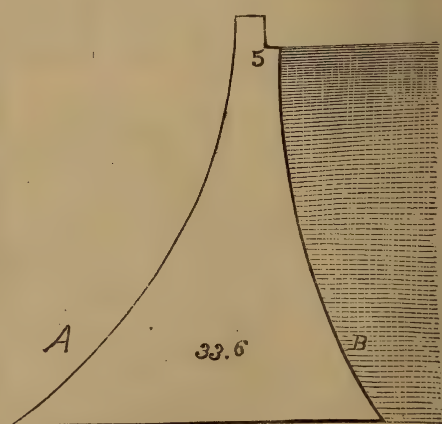


FIG. 11.

The former has a height of fifty metres with a breadth on top of 5.70 metres,

and a limit of pressure of six kilogrammes per square centimetre. The latter has a height of forty-two metres, a thickness on top of five metres, with the same limit of pressure as the Furens dam. By a comparison however, of the profile of the former with that part of the profile of the Furens which lies above the limit A B we see that the thickness has been very considerably reduced, while if we extend the profile to fifty metres and then compare it with the Furens, we find that the pressure nowhere exceeds 8 kilogrammes to the square centimetre.

To return now to the modifications of which this type of profile is susceptible.

MODIFICATIONS OF THE LOGARITHMIC PROFILE.

On a moments inspection of Fig. 8, it is readily seen that, as the inner curve does not anywhere depart very far from the asymptot A S, the first and simplest modification of this curve is to replace it by a right line and thus make the inner face vertical from top to bottom. But the outer curve if treated in like manner, and replaced by a right line, would give us a form of profile which, though it possessed no more thickness at the bottom than was absolutely necessary to withstand the vertical pressure, would at every other point, possess a thickness greatly in excess of the requisite amount, and thus occasion a prodigious waste of masonry. We must therefore, break this continuous slope and substitute for one long line two or more shorter ones each of which makes a different angle with the vertical. Limiting our attention for the present to the first case, and replacing the two logarithmic curves in Fig. 9 by lines,—the inner curve by one vertical, and the outer by two inclined—we have produced for us a profile of the form illustrated in Figs. 12 and 13. The

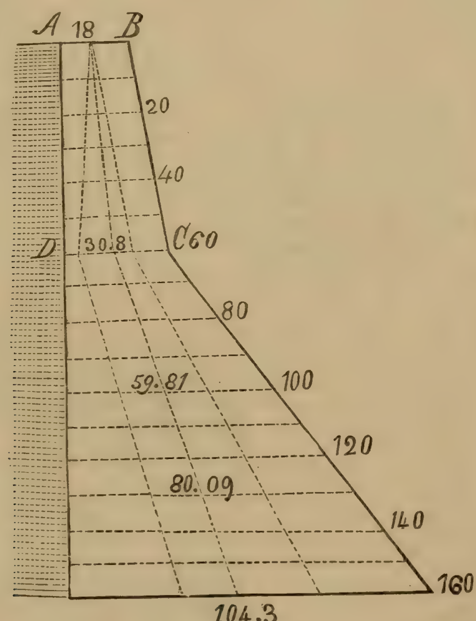


FIG. 12.

question that first presents itself in the discussion of such a profile, is evidently how far down the outer face the point C is to be taken. It comprises indeed, the *entire* discussion. Of course, it is a great advantage, so far as the saving of material is concerned, to throw this point as low as possible, but this is limited by the condition, so necessary to secure stability, that when the reservoir is full the vertical pressure at C shall not be *greater* than the limiting quantity R. Having determined the thickness across the top, which preserving our previous notation, we will call b, the quantities to be determined are first, the vertical dis-

tance of the point C below the top, and second the thickness of the dam at this point, or what is perhaps more easily obtained the *excess* of the thickness at C over the thickness at the top, A B. The distance, A D (Fig. 12) we will call y;

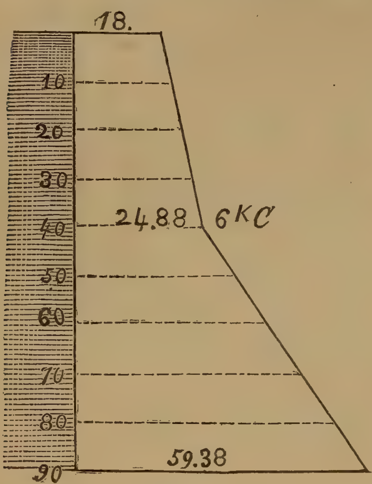


FIG. 13.

the total thickness D C we will represent by b', and express the excess of thickness V C by v. By W, denote the weight of the A B C D (Fig. 14), and by F, the horizontal thrust of the water above D. These two forces act through the centre of gravity O, the former vertically downward and represented in Fig. 14 by

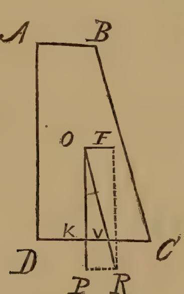


FIG. 14.

the line O P; the latter horizontally and represented in direction and intensity by O F. These two produce a resultant which cuts the base at V, and this point may therefore be regarded as the point of application. From this relation, as we have seen, result two equations $2\left(2-\frac{3u}{l}\right)\frac{P}{l}=$ or $<R'$, and $\frac{2P}{3u}=$ or $<R'$, which are to be used according as u is $>\frac{l}{3}$ or $<\frac{l}{3}$.

In these equations P = W, is, according to the notation of Fig. 14, expressed by $\left(\frac{b+b+v}{2}\right)y\,\delta'$, in which δ' is the density of the masonry; $l=b'=b+v$ and $u=$C V. But $u=$C V$=$K C$-$K V. Now K C may be found by the equation expressing the relation that the moment of the weight of A B C D, with respect to C, is equal to the sum of the moments of the two parts A B V D and B V C into which the area of A B C D may be divided. The moment of the weight of A B C D, with respect to C, is evidently the weight $\left(\frac{2b+v}{2}\right)y\,\delta'$ multiplied by K C; that of A B V D by $\frac{(b+2v)\,b\,y\,\delta'}{2}$ and that of B V C by $\frac{yv^2\delta'}{3}$. Hence, the relation when expressed, becomes:

$$KC\times\left(\frac{2b+v}{2}\right)y\,\delta'=\frac{(b+2v)\,b\,y\,\delta'}{2}+\frac{y\,v^2\,\delta'}{3}\quad . \; . \; . \; . \quad 46.$$

$$KC=\frac{\frac{(b+2v)\,b\,y\,\delta'}{2}+\frac{y\,v^2\,\delta'}{3}}{\left(\frac{2b+v}{2}\right)y\,\delta'}$$

$$=\frac{3b^2+6bv+2v^2}{6b+3v}\quad . \quad 47.$$

To find K E, we have from the two similar triangles O K V and O P R the proportion

$$KV:KO::PR:PO$$

whence

$$KV=\frac{KO\times PR}{3P}\text{ or }\quad . \; . \quad 48.$$

since P R is equal to the horizontal thrust, which, as we see in the early part of our investigations, is equal to $\frac{y^2\,\delta}{2}$; and since P O is equal to the vertical pressure and this is equal to $\left(\frac{2b+v}{2}\right)y\delta'$ we have finally for the value of K V:

$$KV=\frac{y^2\,\delta}{3\,(2b+v)\,\delta'}\text{ or }KV=\frac{y^2\,\theta}{3\,(2b=v)}\quad 49.$$

which latter equation is found by substituting for $\frac{\delta}{\delta'}$ the letter θ. These values given in equations 49 and 47 when replaced in the expression

$$u = \mathrm{KC} - \mathrm{KV}$$

give $$u = \frac{3b + 6bv + 2v^2}{6b + 3v} - \frac{y^2\theta}{3(2b+v)}$$

$$= \frac{2v(v+3b) + 3v^2 - \theta y^2}{6b+3v} \quad . \quad 50.$$

With this value of u we return to equations 24 and 25, and, substituting it, we obtain :

$$2\left\{2 - \frac{\frac{6v^2 + 18bv + 9v^2 - 3\theta y^2}{6b+3v}}{b+v}\right\} \times \frac{\left(\frac{2b+v}{2}\right) y\delta'}{\delta'\lambda} = \lambda$$

and $$\frac{2\left(\frac{2b+v}{2}\right) y\delta'}{3\delta'\left(\frac{2v^2+3b+3v^2-\theta y^2}{6b+3v}\right)} = \lambda$$

These, when reduced and made equal to zero, give us two equations containing two unknown qualities :

$$\theta y^3 - \lambda v^2 - 2b\lambda v + b^2 y - \lambda b^2 = 0 \quad . \quad 51.$$

$$v^2 y - 2\Lambda v^2 - 4bvy + \theta\Lambda y^2 - 6b\Lambda v + 4b^2 y - 3b^2\lambda = 0 \quad . \quad . \quad 52.$$

The first of which is to be used when $u > \frac{b}{3}$, and the second when $u < \frac{b}{3}$. Each of these equations express the relation that when the reservoir is full the vertical pressure at the point C (Fig. 14) shall be equal to the limit R. But we must also take into consideration the inner face, and find an equation expressing the relation that the reservoir being empty, the pressure at D, shall not exceed the limit R. In this case, the face being vertical, the pressure of the water does not exist, and the force P, or the weight of this portion of the dam, acts downwards through the centre of gravity, and

$$u = \mathrm{DK} = \mathrm{DC} - \mathrm{CK}$$

$$u = b + v - \frac{2v(v+3b) + 3b^2}{6b' + 3v}$$

$$= \frac{6b^2 + 6bv + 3bv + 3v^2 - 2v^2 - 6bv + 3b^2}{6b + 3v}$$

$$= \frac{v(v+3b) + 3b^2}{3(2b+v)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 53.$$

With this value of u, we again return to equations 24 and 25, substitute in each, and reducing, have :

$$v^2 y - v^2\lambda + 3byv - 2b\lambda v + b^2 y - \lambda b^2 = 0 \quad 54.$$

$$v^2 y - v^2\lambda + 4byv - 3b\lambda v + 4b^2 y - 3b^2\lambda = 0 \quad 55.$$

By combining 51 and 54, or 52 and 55, we may readily obtain the value of y and v, which are the two quantities we wish to find. It is moreover to be remarked that λ in the above equations is found by dividing the limit of vertical pressure at C and D by the ratio in which the masonry is heavier than water. Thus in calculating the profile of Fig. 12, we have first reduced the limit of vertical pressure per unit of surface from pounds to kilogrammes, and taking the density of water, as given in the French tables, as 1000 kilogrammes and the density of masonry as double that of water or 2000 kilogrammes, we have $\lambda = \frac{\mathrm{R}}{2{,}000} = \frac{60{,}000\,k}{2{,}000\,k}$ or $\lambda = 30$. We thus obtain for λ, a very simple number, whereas had we retained the pressure as expressed in pounds, we would have had a much larger one to handle. In Fig. 13 however, in order to produee a profile of what may be considered as a type of the greatest boldness consistent with safety, we have taken the limit of vertical pressure at 14 kilogrammes per square centimetre, which as we have already stated has been used in several instances in France and Spain. This increases the value of λ to 70. The thickness across the top is in each case the same as in that of the profile illustrated in Fig. 9 ; namely, eighteen feet, but the height of that in Fig. 12 has been reduced to ninety feet. The height AD of the upper part ABCD and the value of v corresponding to it have been found by combining equations 51 and 54. The lower part, by the same equation, by substituting for y the difference between the height AD of the upper part and the entire height of the dam.

The deviation of the line of resistance when the reservoir is full may also be found as follows. Let A B C D in Fig. 15, represent either the upper or lower

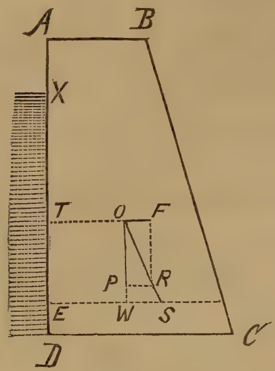


FIG. 15.

part of the dam whose profile is given in Fig. 13, and let it be desired to find the amount of deviation at any section as E F. By O represent the centre of gravity of A B F E, then will O R represent the resultant of the two forces acting on this portion of the dam, and the distance we wish to find will be E S. We will suppose also, in order to cover all cases that the water stands at X. Also let $AB = b$; $AX = l$. $AE = y$; $ES = x$; $EW = h$; and the inclination of the sloping side B C, to the vertical be denoted by α; by δ the density of the masonry and by δ' that of the water. Then by the similar triangles O P R and O W S, we have:

$$\frac{WS}{OW} = \frac{PR}{OP}$$

Now $WS = ES - EW = x - h$ and $OW = TE = \frac{1}{3} XE$ because the centre of pressure (T) of a rectangular plane surface sustaining the pressure of water, is at a point two-thirds the depth of its immersion. Hence $TE = \frac{1}{3}(y-l)$. P R or the horizontal thrust of the water on X E is, as we know, expressed by $\frac{\delta'(y-l)^2}{2}$; and the pressure O P by

$$\frac{(b+b')y\,\delta}{2} \quad \text{or} \quad \frac{(2\,b+y\tan.\alpha)\,y\,\delta}{2}$$

$$\therefore \frac{x-h}{\frac{1}{3}(y-l)} = \frac{\frac{1}{2}\delta'(y-l)^2}{\frac{1}{2}y\,\delta\,(2\,by+2\,y^2\tan.\alpha)\,\delta} \qquad 56.$$

Then replacing $\frac{\delta'}{\delta}$ by θ

$$x-h = \left(\frac{(y-l)^2}{2\,by+y^2\tan.\alpha}\right)\frac{1}{3\,\theta} \qquad 57.$$

$$\text{But } h = \frac{\frac{1}{3}y^3\tan.^2\alpha + by^2\tan.\alpha + b^2y}{2\,by+y^2\tan.\alpha}$$

which, added to equation 56, gives:

$$x = \frac{\frac{1}{3\,\theta}(y-l)^2 + \frac{1}{3}y^3\tan.^2\alpha + by^2\tan.\alpha + b^2y}{2\,by+y^2\tan.\alpha} \qquad 58.$$

This value of x is, of course, to be measured off *from* the vertical side. When the water stands at the top of the dam, the value of l, is zero, but when the reservoir is empty, then l, is equal to the entire height of the dam. The simplest way, however, to find the deviation, is by means of Equation 50, observing that the value of u, when found is to be laid off from the outer or sloping face of the dam; and corresponds to the distance F S in Fig. 15.

THE MARINE COMPASS—CONSIDERATIONS RELATIVE TO CERTAIN FUNDAMENTAL REQUIREMENTS OF IT, WITH SPECIAL REFERENCE TO THE CONSTRUCTION OF THE NAVY COMPASS.

By PROFESSOR B. F. GREENE, U. S. N., Superintendent of Compasses, Bureau of Navigation.

Proceedings of United States Naval Institute.

I.

INTRODUCTORY OBSERVATIONS.

It is sufficiently well known to the members of the Naval Institute that a change in the compass equipment of our ships of war has been gradually going on for a number of years past, until there has come to be nearly a complete substitution of the liquid compass for

the air or dry compass previously in use.

The first introduction into our service of this kind of compass was about eleven or twelve years ago, in the form of a liquid boat-compass, the original models of which were imported compasses of English make, with flat porcelain cards.

The superiority of these instruments over the old and comparatively useless form of air boat-compass was soon evident and generally acknowledged; and yet, for various reasons (possibly from a little conservative prejudice), the new compass was only partially accepted, the outfit for boat equipment continuing for some time to consist partly of liquid and partly of air compasses.

Meanwhile, Mr. E. S. Ritchie, of Boston, who had long been distinguished for his intelligence and skill as a maker of the higher grades of philosophical instruments, finding it expedient, like many others at that time, to turn his attention to the fabrication of "war material" of some kind, solicited and obtained orders to make compasses for the Navy. It was thus that, while making some liquid boat-compasses after the English model, he was led to propose an important improvement, in the substitution of a *buoyant card, with a pivot-pressure entirely at control,* instead of the heavy flat disk otherwise in use.

This was the fruitful germ of Mr. Ritchie's idea, which, from the time he first put it into a practical form, has been in course of continued development, until the compass of the past year, although preserving its original distinctive features, is immeasurably the superior of its early predecessor in all the details of its construction.

Still, our naval authorities, while admitting the improvement, were far from precipitate in changing the compass equipment of our ships; and thus it happened that the new liquid compass was hardly brought into exclusive use, even for the steering-binnacle, until about five years ago, and for azimuth purposes only during the last two or three years. In reality, however, it is but few years since the first attempt was made to adapt the compass-card to azimuth observations by giving it a suitably-divided circle; and it is only within the past year that I have been satisfied the true construction of the compass-card had been finally reached.

It was thus by these cautious and tentative steps, and rather behind than in advance of established convictions, that the liquid compass came at length into general use in the Navy; and the time has arrived when we may, I think, with some propriety, put on record, in a public manner, some of the reasons which have appeared to justify a position in this regard so much at variance with the general practice of all other countries.

I propose, therefore, with your indulgence on this occasion, to present a few considerations relative to the principles which, as I am led to believe, should control the construction of the marine compass; and then, by way of application, to show wherein our practical conclusions have been, or are likely to be, justified by the particular type of compass now recognized in our naval service.

The subject is certainly not a hackneyed one; for, notwithstanding the considerable antiquity of the marine compass, in the general form by which it has been known to the nations of Western civilization—with volumes of history, popular description, and panegyric—I am not aware that a single attempt has hitherto been made to give a rational explanation of its magneto-mechanical action, or of the principles upon which its construction, as an instrument of observation, should depend. And yet the theory of this instrument rests upon a few simple considerations of certain established conclusions of science. The neglect in this particular may, perhaps, afford a sufficient explanation of what appeared, in my first acquaintance with the marine compass, as one of the most remarkable facts in its history—that, as commonly seen in the hands of navigators, *it should be one of the rudest and most imperfect instruments for the accomplishment of one of the most important purposes among the practical pursuits of life.*

There are three properties of the marine compass, so essential to its reliable action and convenient use that they may very properly be regarded as fundamental desiderata. They are:

MAGNET-POWER, SENSIBILITY, STEADINESS.

Let us consider, for a few moments, the precise significance of these terms in their present application; the conditions that appear to be requisite for the most favorable realization of the properties which they represent; and how nearly they are likely to be satisfied by the present Navy compass.

I. MAGNET-POWER OF THE COMPASS.

The more or less complex system called a compass-card, alike with the simple magnetic needle, when balanced for motion in a horizontal plane, has a tendency to return to its position of equilibrium, or rest, whenever deflected from it, which may be called its *moment of deflection.*

The moment of deflection is equal to the *moment of motive force* less the *moment of resisting force.* The moment of motive force is composed of three factors: of which one is the magnet-power (or, perhaps, in more precise phrase, the magnetic moment) of the card; another is the directive force acting on the compass, meaning the whole exterior magnetic force acting in the horizontal plane of the card; and the third factor is the sine of the angle by which the zero-line of the card is deflected from its position of rest.

The moment of resistance is the moment of all the resistances, of whatever kind, to the motion of the card.

All these moments are referred to the point of the pivot as the centre of the compass and centre of moments.*

In relation to the *directive force,* it will here be understood that this term refers to the whole external magnetic force actually effective upon the compass; this being known, in general, on shore, as the horizontal magnetic force of the earth, and on board ship as the resultant of the horizontal magnetic forces of the earth and ship, for the particular heading of the ship, the particular place, and the particular time under consideration.

And, similarly, in relation to the *position of rest,* it will also be understood that the zero-line of the card (supposed to coincide with the magnetic axis of the card), while at rest, is in the position of equilibrium in respect of all the forces, magnetic and otherwise, acting upon it; this being known, in general, on shore, as the magnetic meridian or direction of the earth's horizontal magnetic force, and on board ship as the deviated direction of the compass, or resultant direction of the directive force on board.

The moment of motive force, the directive force remaining the same, varies, therefore, with the magnet-power of the card multiplied into the sine of deflection. It is *greatest* as the card is deflected 90 degrees from its position of rest, when the moment of deflection is equal to product of the magnet-power by the directive force, less the moment of resistance; and it is *least* as the card comes to rest, at or near its previous position, when the moment of deflection is equal to zero; the moment of the motive force being reduced to an equality with the moment of resistance, whatever that may be.

Accordingly, we have for the sine of the *angle of set* (or terminal angle of deflection), or for the arc of set, if the angle be not very large *the moment of resistance divided by the product of the magnet-power and directive force.**

In order, therefore, that the card may always return exactly, or very nearly, to its position of rest, whenever deflected from it, it is necessary either that the moment of resistance be extremely small in comparison with the product of the magnet-power by the directive force,

* If M represent the magnet-power of the card, H the directive force acting upon the card, and δ the angle of deflection of the zero-line of the card, then the moment of motive force, or moment of rotation, tending to restore the card to its position of rest, or statical equilibrium, is expressed by the product of M and H into the sine of the deflection from the direction of H; or,

$$\text{Moment of motive force} = MH \sin. \delta$$

Putting, also, R for the moment of all the resistances, and the moment of deflection is equal to the difference of these two moments; or,

$$\text{Moment of deflection} = MH \sin. \delta - R$$

* When the deflection $\delta = 90°$, we have the maximum—

$$\text{Moment of deflection} = MH - R$$

and when the card comes to rest, the minimum—

$$\text{Moment of deflection} = 0 = MH \sin. \delta - R$$

and, accordingly, the sine of the angle of set,

$$\sin. \delta = \frac{R}{MH}$$

or the arc of set, if small,

$$\delta = \frac{R}{MH}$$

or that this product be extremely large in comparison with the moment of resistance.

Now, the directive force of the earth, in different places traversed by the navigator, varies from about one-half to about twice its mean value; while the directive force on board, especially of iron-built ships, may vary quite as much on different courses of the ship, even in the same locality. Consequently, if, from developed defects of the compass, the moment of resistance be unavoidably large, or, on the other hand, if the directive force on board be much below its mean value, the angle of set, even with the magnet-power of the card unimpaired, will become so much the more appreciable.

It is, therefore, quite essential to the reliable behavior of the compass, under the varying circumstances of a ship's cruise in different parts of the world—

First, that the magnet-power of the compass-card should be as great, in every case, as can be conferred upon it, compatibly with other necessary conditions; or, in other words, that our aim should be to procure not only enough magnet-power for ordinary or average circumstances, but a surplus or reserve for extraordinary occasions of special requirement.

Secondly, that the magnet-power of the card should be as nearly permanent as can be realized through the formation of the card-magnets; and, to this end, that the greatest care should be used during every stage of that process.

Estimating the magnet-power of a compass-card.—These conditions will, perhaps, be more truly appreciated if we consider for a moment the means by which the magnet-power of a compass may be correctly estimated. Three different methods may be employed, with greater or less convenience, for this purpose.

First, the method of deflections.—By this (statical) method, the compass-card whose magnet-power is required is made to deflect a standard magnetic needle at a certain measured distance between their respective centres. The magnet-power of the card is then equal to one-half the cube of the distance multiplied by the product of two factors, of which one is the tangent of the observed deflection, and the other is the directive force; it being understood that the card is so presented toward the magnetic needle that its zero-line is in the magnetic equatorial through the centre of needle.

Secondly, the method of oscillations.—By this (dynamical) method, the compass-card is made to oscillate in its own plane, and the time of one oscillation noted. The magnet-power is then equal to three-tenths of the moment of inertia of the compass-card, divided by the product of two factors, of which one is the square of the oscillation-time and the other is the directive force; it being understood that the units of distance and time are the foot and second.

For the same card, the moment of inertia is constant, and the magnet-power is proportional inversely to the square of the oscillation-time multiplied by the directive force.

For different cards, with the use of the same auxiliary weight, the moment of inertia of the card may be expressed in terms of the moment of inertia of the weight; and the magnet-power is then proportional inversely to the difference in the squares of the oscillation times (with and without the weight) multiplied by the directive force.

Thirdly, the method of torsions.—By this (also a statical) method, the compass-card is suspended in a torsion-balance, and the moment of deflection at any angle balanced by the corresponding moment of torsion. In this case, the magnet-power of the card is equal to the moment of torsion divided by the product of two factors, of which one is the sine of the deflection and the other the directive force.

For the same conditions of torsion, the moment of torsion varies directly as the angles of torsion; and, accordingly, with the same angle of deflection, the magnet-power of any compass-card is proportional directly to the angle of torsion divided by the directive force.

The directive force is thus seen to be an element in each of these methods, as, indeed, it must necessarily be in every estimate of the magnet-power of a compass-card, or of any simple magnetic needle. Still, so long as the required determinations are made at the same place on land, it will be sufficiently exact, within moderate periods, to regard the directive force as constant, in which

case the proportionality of the magnet-power is independent of the directive force.

But, as already mentioned, since this element, under the combined influence of geographical position and the ship's heading, may vary in a several-fold ratio, a proportional change must result in the remaining elements of the determination, provided the magnet-power of the card is unchanged. Hence, generally, in order to any reliable estimate of the magnet-power of a compass, under the varying circumstances of its use at sea, *the directive force must always be known as a necessary preliminary.*

Now, there is no physical difficulty in obtaining absolute determinations of the directive force by well-known methods whenever required; and with this element absolute determinations of the magnet-power of a compass-card could be had, if desired, by either of the foregoing methods. Nevertheless, for all practical purposes connected with the use of the compass, it is always quite sufficient to obtain relative values of the magnet-power for the directive force taken as unity at some convenient initial point.

It would lead me too far from the immediate object of this communication to enter more into details, of a purely determinative kind, in relation to the magnet-power of a compass. It may be sufficient to say, in passing, that the relative directive force, either on board or on shore, may always be found by very simple means, and with sufficient precision for the purpose in view. With respect to the several methods indicated, the second has certain advantages for use at sea: first, that no auxiliary instrument is required; and, secondly, that the removal of the card from the compass-bowl is unnecessary, which, in the case of the liquid compass, is attended with some inconvenience.

Developing the magnet-power of a compass-card.—Now, with respect to the two conditions of the magnet-power previously noted, it will be evident, from the second of the preceding methods, that the question of gaining magnet-power in a compass-card will depend on the possibility of producing a greater increase in the moment of inertia of the card than in the square of its oscillation-time. If, by introducing a different weight and distribution of steel, the moment of inertia is thereby increased m times, while the square of the time is only increased n times, n being *less* than m, there is a *gain* of magnet-power in the ratio of m to n.

Practically, this question resolves itself into two parts: first, that of increasing the magnet-power in the formation of single magnets of given weights and dimensions; and, secondly, that of distributing the magnets upon the compass-card in a manner to increase the magnet power of the card.

First, the development of magnet-power in the formation of single magnets.—This question, which is essentially one of experimental research, has been the subject of numerous special investigations; but by far the most exhaustive inquiry which has ever been made, although open, perhaps, to criticism on certain unimportant points, was that of the late Rev. Dr. Scoresby,* from whose elaborate research the following conclusions may be summarized, as applicable to our present subject:

1. That the selection of steel for compass-magnets should be made from that known generally as the "very best," in the form of thin plates.
2. That the steel, after being cut into pieces of the requisite length and width, should be hardened uniformly throughout, and only annealed or tempered sufficiently to prevent too great brittleness.
3. That the hardened laminæ should be magnetized to their utmost capacity by the most powerful inductive action at command, and each lamina separately tested for magnet-power.
4. That the magnetized laminæ, after being laid together, *in contact*, with the like poles pointing in the same direction, should again be separately tested for magnet-power, and all rejected that show any sensible deterioration.
5. That the proved laminæ should finally be built up in magnet-piles of two or more laminæ in each; it having been conclusively shown that a *compound* magnet, consisting of several proved magnetized laminæ, takes on a higher development of magnet-power than a

* "Magnetic Investigations." By the Rev. William Scoresby, D. D. London, 1843.

simple magnet, in one piece of the same weight and dimensions.

It is not, however, to be understood that the gain in magnet-power from piling is proportional to the number of laminæ in the pile; on the contrary, with equal increments of steel, the corresponding increments of magnet-power are successively smaller, decreasing, approximately at least, in a geometrical ratio with the number of laminæ added to the pile ; so that the practical limit of available gain in this manner is soon reached.

The conclusions of Scoresby, established more than thirty years ago, with respect to the formation of compass-magnets, have been frequently confirmed, although little has been added thereto since that time.

These several conclusions may, therefore be adopted, until, at least, we are better informed, not only as the rules of procedure in obtaining compass-magnets of the highest *intensity*, but as also generally favorable to securing them of the greatest *permanency*.

At the present time, with the use of the comparatively unlimited resources of electro-magnetic induction, the means of magnetization are greatly in advance of those employed by Scoresby. Quite recently a means of heating and tempering the laminæ for compass-magnets has been used by Mr. E. S. Ritchie, which ensures much greater uniformity, not only in the distribution of the degree of hardness sought, but also in the subsequent magnetization.

Secondly, the development of magnet-power in the distribution of magnets upon a compass-card.—If a magnet of uniform section be placed across the centre of a card-circle, its length being equal to the diameter of that circle, its magnet-power and weight will be proportional to the diameter, and its moment of inertia to the cube of the diameter. If, now, we conceive this magnet to be moved in either direction outward, parallel to its first position, taking up positions and reductions of length according to the successive chords, its weight and magnet-power will progressively decrease in proportion to the cosine of the angular distance of the chord from the diameter, while its moment of inertia will progressively *increase* in proportion to a certain function of that angle, reaching it maximum at an angle of 45°, after which it will diminish, till, at the angle of 90°, the chord and all that depend on it vanish together.

Thus, with a magnet at the angular distance of 45° from the centre, its weight and magnet-power are each decreased to 0.7 and its moment of inertia increased to 1.4 of their values, in comparison with a magnet equal to the diameter of the centre ; and if two such magnets be placed upon two equal parallel chords at 45°, each of these qualities will be doubled, or their weight and magnet-power each be 1.4 and their moment of inertia 2.8. Hence, it may be concluded that, by placing magnets symmetrically on equal parallel chords, it is possible to gain in magnet-power, though at the expense of additional weight to be carried by the compass-card.

It will be shown hereafter that there are certain considerations which establish a choice of these symmetric chords for magnet positions. There are two such arrangements which are substantially equivalent, namely, the single pair on chords at 30°, and the double pair on chords at 15° and 45° respectively. The following table illustrates these several relations at one view :

Distribution of Magnets on a Card.

Designation.	One Magnet at Centre.	One pair of Magnets on Chords at 30°.	Two Pairs of Magnets.		
			On Chords at 15°.	On Chords at 45°.	Sum.
Magnet-Power.......... ...	1.0	1.7	1.9	1.4	3.3
Moment of Inertia.........	1.0	2.6	2.2	2.8	5.0
Weight of Magnets.... ...	1.0	1.7	1.8	1.4	3.3

Thus it may be seen that, in assuming a certain practical limit to the increase of section by piling magnetic laminæ in the formation of single magnets (which would be essentially the same for lengths varying between 1.0 and 0.5), and distributing these magnets of equal section upon the parallel chords, according to either of the above-named systems, there will be a material gain in magnet-power, and a larger gain in the moment of inertia, in comparison with the single magnet at the centre.

II.—SENSIBILITY OF THE COMPASS.

If a compass-card on being deflected to any extent in either direction from its position of rest, and then left to itself, return precisely to that position, it may be said to possess *perfect sensibility*; but, on the contrary, if it fail to come precisely to its previous position, the angle of set by which it deviates from that position may be called its *defect of sensibility.*

Now, if there were no resistances to the motion of a compass-card, and if it had any appreciable magnet-power, it would invariably return to its previous position of equilibrium, whenever deflected from it by virtue of the motive action of its deflection, and, consequently, no defect of sensibility could arise.

But, in point of fact, it is a physical impossibility that there should be no resistance to the motion of any body within our immediate cognizance; and, consequently, we must expect, in accordance with our previous assumption, an angle of set, or defect of sensibility, whose value is represented by *the moment of resistance divided by the product of the magnet-power of the card and the directive force acting upon it.*

There are, in reality, two different resistances to the motion of the card: one is the friction of the pivot; the other is the resistance of the medium, air or liquid, in which the card moves within the compass-bowl. The former is a constant; the latter is a variable, depending on the velocity of the card at any particular instant of its motion. The moment of resistance, already referred to, consists, therefore, of the moment of friction at the pivot and the moment of resistance in the medium, both moments being referred to the point of the pivot as the centre of moments. The moment of resistance opposes the motion alike during the increase and during the decrease of the angle of deflection.

The moment of friction consists of three factors: the pressure between the rubbing surfaces, the mean radius of the area in contact, and the coefficient of friction; the latter depending on the physical qualities of the pivot and cap, such as hardness, smoothness, etc. All these factors are essentially constant for the same card, except as they may be liable to change with changes of condition.

The resistance of the medium is more complex; for it not only involves several distinct elements, but its law of action is somewhat uncertain under considerably varied circumstances of the form and velocity of the moving body. Nevertheless, it appears to be certain that the resistance of a medium, properly so-called, is solely a function of the velocity, of the moving body, involving no absolute term independent of that velocity. As to the form of this function, it is far less certain; but we are justified, from the results of experimental research on this subject, in concluding that the moment of resistance of the medium to the motion of a body of unyielding form, like that of a compass-card, is represented by a product of five factors—the square of the velocity of the card, its section of resistance, the mean radius of that section, the density of the medium, and the coefficient of resistance; the latter depending on the form of the card, and possibly, also, on the velocity, in view of the considerable variation in this element during the motions of the card. Of these factors, all but the first and fifth are sensibly constant for the same compass; and of the fifth there is only some doubt whether it can always be expressed as a constant for the same compass, or must be modified somewhat for the variable velocity.

THE report of the Swansea Wagon Company, presented at the ordinary meeting, shows a disposable balance of £14,110 18s. 11d., of which £5,919 18s. will be paid in dividend on the preference and original shares.

OCEAN STEAMSHIP NAVIGATION—ITS PERILS, AND HOW TO AVERT THEM.

By Capt. S. P. GRIFFIN.

Written for Van Nostrand's Magazine.

II.

With the knowledge thus obtained, we can proceed to select a suitable instrument for making sound signals. It is not worth while to speak of the bell, except to condemn it as being unfit for sea coast use. It may do tolerably well about harbors, in narrow channels, on light boats for local purposes only, but as an aid to navigation, to a vessel running in from sea, it is almost worse than useless, because it may deceive the man who has not had any experience with it, he trusting to hear its tones at the regulation distance, runs on until he becomes involved in perils that are speedily followed by destruction.

The steam whistle is a great improvement upon the bell, and the steam siren is superior to the whistle. Of the latter instrument, Professor Tyndall remarks: "That in almost all cases it may certainly be relied on at a distance of two miles."

Professor Tyndall is high authority, and as the scientific adviser of the Elder Brethren of the Trinity House, he conducted an inquiry into the subject of fog signals, commencing in May, 1873. The instruments with which he experimented were air trumpets, horns with vibrating steel rods, air whistles, steam whistles, an American siren, and three guns, one an eighteen pounder, a five and a half inch howitzer, and a thirteen inch mortar; gongs and bells were not included, because previous observations had clearly proved their inferiority to trumpets and whistles.

Seamen have always known that sounds are transmitted best from an elevated station; in a heavy gale you can distinctly hear the voices of the men aloft, whilst at times they cannot hear a word from deck, even when a trumpet is used. Seamen have known also from circumstances of very common occurrence in their experience, that a fog is very favorable for conveying sound. These two important facts they learn in the school of practice. The Professor learned them after a series of elaborately conducted experiments.

Professor Tyndall established two stations for his experiments, one at the top, the other at the bottom of the South Foreland Cliff; a vertical distance of 195 feet separated them; "Comparative experiments at the outset gave a slight advantage to the upper instruments, they, therefore, for the most part were employed throughout the subsequent inquiry." In a paragraph towards the close of his report, the Professor says: "Happily, the experiments thus far made are perfectly concurrent in indicating that at the particular time when fog signals are needed, the air, holding the fog in suspension is in a highly homogeneous condition, hence, it is in the highest degree probable that in the case of fog, we may rely upon the signals being effective at far greater distances." This I suppose is enough to settle the questions as to the advantages to be derived from an elevated signal station for sounds and the superior condition of the atmosphere during fogs for their transmission.

Professor Tyndall gives a preference to the American siren over all of the other competing instruments; however, he speaks of the gun as being "entitled to rank as a first class signal," and recommends that further experiments be made with it, and that it ought to be of the most suitable description, also that the commanders of the Holyhead boats are unanimous in their commendation of it.

The guns used by the Professor in the course of his experiments, it is seen, were not of the right description, they did not burn enough powder, and they were entirely unaided by any acoustic device. We have seen the old-fashioned, long thirty-two pounder tried with eight pounds of powder, and have heard it at remote distances—the guns of a frigate, firing a salute in Monterey Bay, were heard in San Francisco Bay, the distance

in an air line being 75 miles. At Sandyhook, a striking contrast in favor of guns over the fog signal instrument mounted there, has been repeatedly observed ; beyond the farthest reach of the steam siren, vessels heard distinctly the reports of the guns that were undergoing tests at that place.

Seamen have great faith in the superiority of guns for producing fog signals ; they believe that the report of a gun of suitable dimensions can be heard at a greater distance than the blast of a steam whistle, or the more powerful sound of a siren ; they know that at night its flash can be seen through a fog of no mean density ; they feel a confidence in guns, that they have not in favor of any other instrument, and as aids to navigation are intended for the benefit of the navigators, let them have what they know to be the best to suit their necessities, and in the name of common sense, under any circumstances, let them be consulted, let them have a voice in the selection of instruments, and locations for mounting them.

There are plenty of old guns retained by Government about the navy yards, condemned as useless for purposes of war, let us have them to subserve the interests of peace. Mount one of these guns upon an elevated platform ashore, or on the deck of a light-boat, and during periods of fog fire it at intervals of five minutes, using eight pounds of powder, wherever a sea coast fog signal is needed, and most assuredly there will be fewer vessels lost than there are now. Late papers tell us that the Admiralty, alarmed at the loss of the Vanguard by collision with a consort in a fog, has ordered that in future guns shall be used as fog signal instruments.

To convey the human voice to more than ordinary distances man uses a trumpet ; to transmit the sound of a siren a trumpet is also used; then give the gun a chance, and send its loud mouthed report with thundering echoes through a trumpet too. Steam whistles and sirens of the present power may be good enough for coasters, pilot boats, and for other vessels that have had a fresh departure, but they are only a little better than the bell to the ship running in from sea guided by dead reckoning alone, for the limit of their sound leaves too small a margin beyond the danger line. The change to the gun will be easy enough; the only expense will be in transporting it to its assigned place and mounting it; it will hardly require additional hands to the present complement allowed to fog stations, the powder can be drawn from what is annually condemned as not being up to the standard in strength for projectiles, but still retaining enough of its noisy properties.

At the time when this paper was first written, the intelligence of the loss of the German steamship Schiller, Captain Thomas, was just received. Her case was used to illustrate the importance of what has been said about needed reforms, and as it is, doubtless, very well remembered, I will use it now. Since her terrible wreck on the Scilly Islands, nothing has occurred to change my views as to the causes that brought it to pass, and it is a peculiarly interesting one, for it occurred upon a familiar route, and it embraces completely the reasoning that has been adopted in the preceding pages.

The Schiller was a large full-powered first class steamship, about a year old, thoroughly equipped and well manned. She was one of a line of steamers in the trade between New York and Hamburg, calling at a port or ports in the English Channel. In pursuing the course usually followed by vessels of her line, she would have passed south of the Scilly Islands, but well within the limit of visibility of Bishop's Rock light, and then she would have hauled in for Plymouth, her destination.

Bishop's Rock, the southwesternmost outlying danger of the Scilly Islands, has a light and a bell upon it ; in nights of clear weather, the light shines forth its warning rays to a distance of sixteen miles ; in fogs, it is, of course, obscured and useless as an aid to navigation, and the bell is called into requisition to perform a service that it is not equal to.

By the reports that have come to us, we learn that this important steamship had been without astronomical observations for position for three days immediately preceding the wreck ; that the weather had been thick and stormy, that her captain had been on deck several days and nights consecutively ; that at 9 P. M. of the 7th May, in a dense fog with a breeze from S. W., believing the

ship to be close to the land, the order was given to take in all sail, the courses was altered to S. E., and the engines slowed down to give a speed of ten knots through the water. At 10 P. M., one hour after altering the course, one hour at a speed of ten knots, she struck on Retarriere Ledge, a danger situated S. E. $\frac{5}{8}$ths of one mile from Bishop's Rock. Unhappily, she ran ashore at the period of low water, for the rising tide had much to do with the loss of life that followed.

Three days before the wreck, the Schiller was about one thousand miles west of the Scilly's in bad weather. It is anxious work to run in from the wild Western Ocean, and to straighten up Channel by dead reckoning alone ; and it was good navigation on the part of Captain Thomas to run his steamship through cloud and mist and fog along a track so closely approximating to the true one, and it was his great misfortune to be at last thrown off by insufficient allowance for currents or for local attraction as he came up with the rocks. He believed that he was near Bishop's Rock at 9 P. M., and he did what he thought to be at the time necessary for the safety of his ship, he took in sail, reduced the speed, and headed more to the southward.

The sixty fathom curve of soundings sweeps around in the arc of a circle of which Bishop's Rock is the centre, having a radius of fifteen miles, the fifty fathom curve with a radius of five miles, and the forty fathom curve approaches the Rock to a mile on its south side, and one and a half miles on its west side.

Now, taking the speed of the steamship, and the course she steered after 9 P. M., we find that at 9 she was five miles inside of the sixty fathom curve and nine and a half miles from Bishop's Rock, at 9.30 she was just on the inside of the fifty fathom curve and four and a half miles from the Rock. From this it can be seen that if she had headed only a half point more to the southward she would have cleared the dangers, or that a cast of the lead at 9 and another at 9.30 P. M., would have given sufficient warning of peril to a prudent navigator; but the course that was at first decided upon was adhered to, and sounding appears not to have been thought of. We learn that four officers, including the captain, were on the bridge, and that two men were on the look-out forward.

About 9.55 P. M. she must have been abreast of and close to leeward of Bishop's Rock—probably not two cables length from it—to strike Retarriere Ledge, on the course that she steered, she had to pass inside of the Rock and almost within hailing distance of it, yet they neither saw or heard anything; this seems to be incredible. The atmosphere was in a peculiarly favorable condition for the transmission of sound, she was to leeward of the bell ; the regulations of the Board of Trade require the bell to be struck in foggy weather, and the light-keeper swears that it was struck. Alas ! it was not heard, for even then prompt action would have saved her.

There are other circumstances in this distressing case that puzzles investigation ; seamen know that as she passed close to leeward of the Rock, an appreciable change must have occurred in the force of the wind, in the character of the sea, and the smell of the rock must have been strong, particularly at low water, yet the indications were unnoticed.

What was the cause of this apparent neglect, or inability to think of the most ordinary precautionary measures, or to distinguish the presence of certain well-known signs ? How are we to account for the loss of this splendid steamship, so well manned, and hitherto so skillfully handled ? May we not attribute it to the operation of the causes that I have been speaking of ? There cannot be any doubt about it. The three or four days of bad weather without observations, preceding the wreck, the care and perplexity of running by dead reckoning alone over a thousand miles, a position around which she was to haul in for her port, the sea crowded with inward and outward bound vessels, the currents variable in their strength and uncertain in their direction, required extraordinary vigilance on the part of her officers, the strain brought upon them, and the almost constant exposure under the custom of "watch and watch," was quite enough to use them up. The Captain was probably in a worse condition than any of his mates, for he is said to have been on deck most of the time, and this is not surprising

for he was responsible for the safety of the ship, his anxiety was the greatest, and he felt the necessity of giving his personal attention to the duties of the deck.

So that when the critical time arrived —when the perilous situation of the steamship demanded for her preservation, the exercise of the clearest judgment, and the employment of the keenest faculties, the Captain or the mates did not possess either one or the other of them, they were not in a condition equal to the emergency—their minds were clouded, their senses were blunted by overwork, exposure and insufficient sleep. If they had been in a fresh and vigorous condition of body and mind, they would not have overrun the distance, they would have reasoned out the necessity of sounding, they would have become aware of the closeness of Bishop's Rock in spite of the fog. Does any one believe that if we could have put on board of that ill-fated steamship an intelligent shipmaster and four mates, all clear headed and strong at 9 P. M., when the order to reduce the speed was given, that she would have been lost? Working from her position of three days before they would have appreciated their situation, and have at once adopted the simple remedies that were adequate to save her.

I hope that the evils of the custom of "watch and watch" are now understood, but, as great as we know them to be, it is more than probable that the Schiller would have been saved if a gun of a suitable description had been used for signals, instead of the bell on Bishop's Rock, or if it had been mounted on any convenient ledge in the immediate neighborhood and properly served, the wreck would not have happened, for its loud-mouthed warning would have been distinctly heard, even by worn and weary men, far enough off to have turned her upon her course, and thus have preserved the lives and property so sadly lost.

LIFE RAFTS.

From "The Engineer."

Among the numerous lessons which the details of the wreck of the Deutschland presents to our notice, there is not one more striking than that offered by the total inefficiency of the boat service in time of need. A large passenger steamer, belonging to a company whose special province it is to carry the mails and passengers between Germany and America, is stranded upon a sandbank within a few miles of a lightship, with which she is able to communicate her distress by means of signals, and yet so badly off is she in the matter of boats and the means of lowering them that but one can be launched, and that one so small that only three men are able to escape in her. There appears, however, to exist an impression that even if the boats had been sufficient in number to accommodate the whole of the crew and passengers, and had been provided with the most perfect system of lowering in existence, still it would probably have been impossible to have lowered them in safety on account of the heavy sea which was running. In our own Passenger Act it is laid down that boats shall be provided numerous enough to carry the whole of the crew and passengers; but it is manifestly impossible to hang all these boats in davits round the side of the vessel, and therefore they have to be carried stowed inboard, sometimes one within another, in places where it is almost impossible to get at them when wanted, and where they are liable to damage. It is therefore evident that to insure the safety of the passengers in case of any accident happening to the ship, it is not enough to insist on a certain number of boats being carried, but that some other means must be provided of escape from a stranded or sinking vessel in such a case as that of the Deutschland, where the practicability of launching even the boats hung in the davits is extremely doubtful.

For this purpose many different devices have been invented, out of which

some five or six have especially come before the notice of the public. The first of these is the tubular life-raft, which was originally made of some inflatable material, and of which a typical one, the Nonpareil, made the journey from America to England under sail. The United States' Commissioners who were appointed to investigate the subject, objected to the inflation on account of the time it would take, and the life-raft now adopted is made of metal, and consists of two tubes, pointed at either end, and connected by girders, and carrying air and water-tight tanks holding provisions for a week for twelve persons. These tanks are fitted between the girders, and have a screw cap both at the top and bottom, so that it is immaterial on which side the raft alights in the water. The rafts themselves are so light that four men can throw one of them into the water over the side of a vessel. A very similar apparatus was invented in 1852 by Mr. Richardson, and was called the Challenger Lifeboat. This consisted of two circular tubes of tinned iron, 2 ft. 6 in. in diameter, each tube being divided into twelve compartments. The tubes were placed 3 ft. apart, and the ends turned up and joined. The tubes were held together with iron arches, on which the grating and seats were fixed. The raft was provided with sixteen oars, as well as two lugsails, topsails, and jib. There was, however, no special contrivance for launching this raft, other than that employed for ordinary boats, which we have already pointed out as being extremely defective. Mr. John White, of Cowes, seems to have been the first to invent a method of overcoming this difficulty, by his contrivance called the lifeboat bridge. This consists in converting the bridge, which is generally used merely as a means of crossing from one side of the vessel to the other, into a lifeboat. This lifeboat is made a little longer than the breadth of the vessel, and is carried upon ways, the platform of which, being pivoted in the centre, can be lowered at either end at will by knocking down a couple of staunchions on which it rests, when, the other end being elevated, the boat is at once shot into the sea, its bilge-pieces forming the skids, which fit into the launching ways. A great advantage of this method of stowing and launching the lifeboat is, that it is not liable to be damaged, or washed away, as those hung in davits outside the ship. A plurality, too, of these bridges may be carried, according to the size of the ship, and, by a peculiar arrangement, can be turned fore-and-aft if required. A bridge boat, 40 ft. long and 10 ft. wide, will carry 125 persons, so that three of these—which can be arranged as two transverse bridges, 40 ft. apart, connected by a fore-and-aft bridge —would be capable of containing a crew of 375 persons. We understand that the Admiralty have ordered the Orontes troopship to be fitted with these bridges. Mr. H. Christie, of the Peninsular and Oriental Steamship Company, and Mr. Roper, have adapted Mr. White's method of launching to peculiar forms of life-rafts. Mr. Christie's raft, which is rectangular in form, consists of a wood framing, the spaces between which are filled with air-tight tin cases. After it is afloat, a water-tight bulwark can be formed around it, by raising a number of hatches pitted upon hinges. Mr. Roper's life-raft is very like Christie's in general construction, but his modification of White's launching ways consists of doing away with the central pivot, and lowering either end by a mechanical arrangement worked from the bridge itself; but whereas Christie's life-raft, like the American tubular rafts, is reversible, Roper's is not; and this, we must say, we consider a decided disadvantage. Both Christie's and Roper's rafts, however, labor under another disadvantage, namely, that of having but little freeboard; for if the passengers on a raft in a heavy sea are continually washed over by the sea, they are in danger of perishing by the cold before they can reach any place of safety.

A life saving vessel just invented by Mr. J. A. Stockwell certainly appears to possess some very important advantages over the three plans we have just discussed. In the first place, from its shape it is more stable and can carry more passengers than White's lifeboat; and in the second place, it has a high freeboard, and is therefore not so liable to be washed over as either Christie's or Roper's raft. It consists of a circular vessel, 20 ft. broad, and constructed of an annular cylinder 5 ft. in diameter,

round which seats are built inside. These seats, being made water-tight, can carry fresh water and provisions for the passengers. Over this annular cylinder a battened deck is fitted by means of knees, so that the sea can break up through it, and there is therefore not much fear of the vessel being capsized.

The navigating qualities of the vessel are complete, for she is provided with masts, sails, and rudder, a stem or projecting cutwater, and a drop keel which can be lowered or raised at will. The vessel would be divided into four watertight compartments by bulkheads with sluice valves, each compartment having a separate hatchway fitted with a ventilating cap, constructed so as to admit sufficient air and at the same time prevent water from entering. Each compartment is also provided with watertight scuttle-lights. A pump, too, is fitted to draw off any water which may get inside, communication throughout the whole vessel being maintained by means of the sluice valves in the bulkheads. On the outside of the vessel a rubbing plate of wood is worked, so that she could go alongside any ship or be boarded by a boat without danger. Life-lines are fitted round the edge 60 feet long, and carrying a cork ball at the end by which persons in the water might be saved.

One particular advantage claimed by the inventor is the fact that in this life vessel there is so vast a quantity of displacement, in proportion to the size, that it would be impossible to overload it with passengers, because there is not sufficient deck space to hold them, whereas the ordinary lifeboat, when overcrowded, is often rendered useless. The method of launching these vessels is rather peculiar. They are carried amidships raised above the deck, and placed on ways made of two angle irons forming a groove, in which the skids of the angle iron, which forms the bilge keel of the vessel when afloat, slide. Outer ways, in combination with these ways, can be slid out beyond the side of the ship, so that the life vessel can be launched clear of the side. The ways, however, instead of being straight, as in White's plan, are curved to the segment of a circle, and under the launching cradle horizontal cast iron rollers are fitted to prevent all friction or jamming in the groove of the launchways. The launch of one of these life-saving vessels from a hulk at Blackwall, some few weeks since, was perfectly successful, and we should be glad to see it further tested on actual service. We think, however, the time has arrived now when it becomes the duty of the Board of Trade to take the matter in hand. If they were to offer a premium for the best life-saving raft or vessel answering certain conditions, and to give all those competing a severe test in heavy weather, the Passenger Act might be further amended by a clause to the effect that all passenger vessels should carry a life raft of certain proportions.

HYDRAULIC EXPERIMENTS.

From "Engineering."

The typical English hydraulic engineer is the most complacent of beings; with his shelves loaded with old folios and new editions he is prepared to face the cross-examination of any awe-inspired deputation of spirited inhabitants, with the equanimity characteristic of the witness who really does know all about it, and means to speak the truth. There is little excuse required for the credulity of the members of the deputation. Works on hydraulics by long-forgotten authors can be picked up at any bookstall, and if the date happen to be somewhere about 1700, and the author as usual advances unfailing formulæ for every imaginable case, the general public may well be excused for assuming that the mine of information bearing upon hydraulic science has been so well worked that it will not repay further exploration.

Even the earnest student may for a long time remain in a happy state of ig-

norance concerning the present state of the science, but sooner or later, when dealing with some actual or hypothetical case, the truth bursts upon him that the results given by the formulæ of one cherished authority are entirely at variance with those derived from a no less venerated master, and that in short the multiplicity of his results is only limited by the number of his references. After the first disenchantment there will be little peace for him, for the further his researches are extended the more preposterous will appear the disproportion between the vast mountain of deductions and the poor little molehill of facts. Assume for the moment that our young engineer begins by conferring with his "Neville"—which is a fair sample of an English text-book on hydraulics, and serves the purpose of our illustration better than another, since a new edition has recently been called for—and assume further that he is seeking the probable mean velocity in an irrigation canal of given fall and cross section.

At the end of his volume he will find convenient Tables giving by inspection the very element he wants, in inches and hundredths of an inch. He may be curious to know to whom he is indebted for these very pleasing and conclusive results, and the text will inform him that it is to Du Buât. The name will doubtless be already familiar to our student, but if he still "asks for more," and persists in following up the trail, he may be somewhat startled to find that the date upon the Tables should be 1785, rather than 1875, since it was in the former year that the Chevalier Du Buât and the Abbé Bossut published their conclusions—which, in many instances, were based upon experiments carried out by M. Couplet, the engineer of the Versailles Water Works in the almost prehistoric period of 1732. He may possibly infer that deductions which have thus held their grounds for upwards of a century must necessarily be sound and trustworthy, but of course the inference would be entirely wrong. The tabulated velocities, though expressed in hundredths of an inch, are in reality but the wildest guesses at the actual velocities in irrigation canals of ordinary dimensions. Colonel Cautley relied upon Du Buat when he laid out the Ganges Canal, and found him but a rotten reed, for the water in every instance tore along at unexpected velocity, and erosion of the bed and destruction of works followed in its wake.

Du Buat then must be put upon the top shelf of the book-case, and it will be just as well, when the steps are there, to carry up every English work in which the name of Brüning, Girard, Bossut, Prony, Eytelwein, or D'Aubuisson, are continually recurring as authorities, against whom no action can be taken. In this general clearance Beardmore, Downing, Box, and almost every other hydraulic text-book compiled by Englishmen will, with more or less hesitation, have been shelved, and the young engineer will then be able to form a fair estimate of the contribution which his countrymen have made to the common fund of knowledge concerning the laws governing the flow of water. We think we may venture to state, without fear of contradiction, that up to the present date the science of hydraulics has not been materially extended or its progress appreciably accelerated by the labor of any English experimenter.

When M. Bazin presented his report to the Academy of Sciences in 1863, many illusions which had almost universally prevailed during the preceding century were rudely dispelled, and from the multiplicity of fresh data the science received a new impulse. Perhaps the most important of all the facts elicited was the vast and unexpected influence of what may be termed the *skin* of the channel upon the speed of the current. At the very time when these conclusive experiments were being patiently carried out by French engineers, there were not wanting two English engineers of the first rank in their profession to condemn in vigorously sarcastic terms the initiators of a series of experiments undertaken to ascertain the actual discharges of pipes made of various materials. One of these unfortunately influential critics maintained that "in an engineering point of view it was perfectly immaterial whether the surface were brick, iron, or glass, since the resistance in all instances must be the same," whilst the other one with characteristic bluntness and assurance added that "any further experiments involved a mere waste

of money." It is rather amusing to reflect that the latter gentleman was quite recently appointed a member of the committee to advise with Mr. Froude as to the experiments which should be undertaken to ascertain the resistance of steamships, for Mr. Froude's views on skin resistance are tolerably well known, and the alliance was, at least, a curious one. In the experiments referred to, the state of the copper sheathing was carefully noted by Mr. Froude, and its resistance was stated by him to be about the same as if the immersed portion of the hull were half covered with calico and half varnished—a significant refinement when it is remembered that almost every popular formula given in our text-books draws no distinction even between glass and earthwork if a pipe or channel be in question.

The results of the experiments instituted by D'Arcy, and continued by Bazin, together with the well known Mississippi investgations, afforded a grand mass of facts at which Bazin himself, Gauckler, and many others have since labored with a view to deduce a comprehensive formula which shall include every case, from a street gutter to a mighty river. The most successful of all the workers in this field are perhaps Ganguillet and Kutter, whose laboriously deduced comparative results have been reproduced in almost every other language but our own. Mr. Jackson bases some of his Tables upon Kutter, and so far as we know, that is the only instance in which the deductions of the latter have been referred to in an English work. Our own attention was first attracted to Ganguillet and Kutter's labors through a notice which appeared in the Proceedings of the Dutch Institution of Engineers. Perhaps it is not too late, even now, to induce Mr. Forest to append a full translation of the German original in an ensuing volume of the "Proceedings." Possibly some of our Indian brethren may have already translated the memoir; if our memory serves us those of Bazin and Gauckler have been republished at Roorkee though not at London.

It is only by thus taking a retrospective glance over the whole field that we can fully appreciate the precise value, and, we may venture to add, national importance of the series of hydraulic experiments which have recently been so successfully inaugurated by Captain Cunningham, R. E., of the Thomason College, Roorkee. We have seen that the contribution of Great Britain to the general store of knowledge has been perfectly contemptible and unworthy of a great nation which in its Indian irrigation works has finer opportunities for such researches than any other country on the globe. The prestige of English engineers has not even held its own in recent times, and the English element is as persistently ignored in Continental text-books, as with the foreign policy of the country in diplomatic circles before the reaction caused by the purchase of the Suez Canal shares. To recover their prestige, English engineers must pursue an equally bold policy. An exhaustive series of hydraulic experiments by the Government engineers at Roorkee would at once restore the English element to every engineering text-book on the Continent, where at present it is contemptuously ignored. Surely now that a suitable man is found in Captain Cunningham to carry out the experiments there can be no "rocks ahead." Even if we elect to be judged as a nation of shopkeepers, the experiments can be justified, as they will return the necessary outlay many times over in a few succeeding years. Lord Salisbury is half an engineer himself, and holds the reins—cannot he be induced to interest himself in the science of hydraulics?

Mr. Froude is now conducting for the Admiralty one of the most complete series of experiments ever yet undertaken by any nation. The laws governing the resistance of solids moving through water are thus in a fair way of being ascertained, and if Captain Cunningham undertakes in like manner to determine the laws governing the flow of water in large channels, we shall indeed make ample reparation for the petty filching and pilfering from our neighbors' stores in which we have hitherto indulged.

Some of the results already obtained by Captain Cunningham—as will be seen from the summary of his report—are both novel and interesting. The establishment of the principle of "unsteady motion" will clear up many anomalies;

it may, for instance, explain the differences in the mean surface velocity at the Solani Aqueduct as measured in 1874 and 1863. According to Captain Cunningham the mean surface velocity was .927 of the central velocity, whilst in the earlier experiments, if Mr. Logan be correct, the ratio was .88 only. The surface velocity curve in the Solani Aqueduct was in form a flattened ellipse, and of such regularity that the temptation to Captain Cunningham to find its equation proved irresistible. We do not see what use the equation will serve unless it be to enable us to reproduce approximately the surface velocity curve in the Solani Aqueduct, which can, of course, be better from the observations direct. We have now before us a pretty extensive assortment of surface velocity curves. In some, as in the instance of the Solani Aqueduct, the bank is tangent to the curve, but in others it is normal to the same. In one example where the cross section was very similar to that of the Solani embankment channel, the bank on one side was tangent to the curve, and on the opposite side at an angle of 45 deg. nearly. We may add that many of the curves we refer to were measured by Mr. B. T. Moore, M. A., a highly competent and scientific observer, as Captain Cunningham will readily concede, since he makes use of Mr. Moore's formulæ in the computation of his areas.

We differ then from Captain Cunningham—and we are glad to say it is the the only point on which we differ—in thinking that the fact of his surface curve being a "quartic ellipse" is an interesting result of the experiments. To us it is no more interesting or suggestive than would be the discovery that the curve of Primrose Hill was a true conchoid. We wish it were otherwise, and that some short cut could be found to the desired end, but with the diagrams before us we cannot but feel that many months' hard work have to be gone through before any generalization can be usefully attempted. It is only fair to Captain Cunningham to state that he attaches no undue importance to the discovery, and that in all probality any mathematical work is to him rather a pastime than a labor, even though the thermometer be at 120 deg. in the shade.

The Roorkee experiments afford a further confirmation of the fact that the central vertical velocity curve is approximately a parabola to within a short distance of the bottom. This truth was elecited at a very early period in the history of hydraulic science ; we remember seeing it recorded in an old German tract on hydraulics formerly in Smeaton's possession, and at least 150 years old.

We are pleased to note that Captain Cunningham's preliminary report proves him to be not merely a mathematician, but a practical man who will know how far he can safely apply his facts in the development of a comprehensive theory. We are not of those who contend that every practical suggestion of a pure mathematician *must* be wrong, but we are bound to admit that too great faith in theoretical deductions unverified by direct experiments sometimes leads to an undesirable result. An amusing instance of this occurred a short time ago at a meeting of one of our scientific institutions, when the subject under discussion was the marvellous speed of one of Thorneycroft's launches. A deservedly eminent shipbuilder, well known for his persistent and able advocacy of his own theoretic deduction that to obtain a certain speed the ship must be of a certain minimum length — about five times as long as the boat under discussion—was attempting to show by a reference to the lines of the boat exhibited on a diagram hanging on the wall, that after all her performance was just as it should be. The apoplectic symptoms commonly indicative of "trying to come" what Mr. Weller termed "a kind o' quiet laugh" being alarmingly apparent in Mr. Thorneycroft's countenance, it was suddenly discovered that the diagram had accidentally been hung upside down, and that although the demonstration was progressing as well as could be wished, it of course implied the assumption that the boat traveled stern foremost.

It would have mattered little had it been otherwise. Any one who had not seen the boat at high speed might have sat quietly down and calculated her "augmented surface" and propable speed in the most confident manner, but would afterwards have been quite aghast to find that when fairly settled down to her work she just lifted her bows clear

out of the water, showing daylight under the first 6 ft. of her keel, so that as far as speed was concerned her fine razor-like cutwater might as well have been replaced by a slice off the Popoffka. All engineering history tends to prove that it is hardly safe to make the simplest theoretical deduction in hydraulic science. Before Macneill's experiments of some forty years ago it was always assumed that the resistance of a vessel moving through water would necessarily vary as the squares of the velocities. The experiments did not bear out this theoretical deduction, and so contemporary critics did not hesitate to throw over the experiments: "Only think, gentle readers!" says the *Mechanics' Magazine* of the day, "the illustrious Newton and his immortal band of followers taunted with ignorance of the first principles of philosophy by John Macneill. Is it not as if the beetle were to scoff the eagle for its blindness?" Every engineer now knows that we need not go beyond Her Majesty's navy to find resistances not merely differing slightly from the squares of their velocities, but hardly comprised with the limits of $v^{1.4}$ and v^4.

An experienced experimentalist such as Captain Cunningham, will of course carefully guard against making any such rash assumption as that twice two are four. The Royal Commission on Iron Structures found when cast iron-bars were in question that 2×2 was much more like 3 than 4. Mallet ascertained that the multiplication table required similar amendment in the case of wrough-iron forgings, and we have no doubt if the ghost of Herr Musschenbrock should ever encounter Mr. Lister of the Liverpool Docks, there will be a very pretty altercation as to whether the cube of 12 is really 1728 or only 1000, when pitch pine is concerned. That two halves are equal to the whole may be an axiom sound enough for Euclid, but not so for the engineer. If, for instance, he ventured to assume that the two halves of a flat steel bar, divided longitudinally by shearing, are equal in tensile strength to the original undivided bar, the conclusion might in some instances lead to disastrous results.

In speaking thus we have no intention to depreciate the labors of mathematicians, but having gone through the mill ourselves we know—and in this Mr. Froude will bear us out—that an entire series of laborious experiments has not unfrequently had to be discarded in consequence of the neglect of some detail of theoretical insignificance. An unpractical scientist and an unscientific practioner are alike undesirable as an experimentalist. The former fixing his eyes on some distant eminence moves straight ahead until probably he is plunged overhead in a morass or quicksand; the latter picks his steps painfully and cautiously enough, but before long unknowingly presents his back to the desired goal. Captain Cunningham we feel sure will avoid both evils, and take the shortest practical route to the point at which he aims.

A very complete organization will necessarily be required if the hydraulic experiments now commenced be carried on to a fitting completion, and doubtless the best practical step would be to put Captain Cunningham in communication with Mr. Froude. We think also that some of Mr. Moore's ingenious instruments, notably the self-recording current direction indicator, one of which is with the Artic expedition, might in Captain Cunningham's hands lead to the development of some unexpected and valuable results.

In conclusion we can assure Captain Cunningham that his labors will be watched with interest by engineers at home, who are glad to find him following thus worthily in the steps of his father, General Cunningham, now at the head of the Archæological Survey of India, and of his uncle, Colonel Cunningham, whose loss the literary world has within the last few weeks had cause to deplore.

A Pittsburg correspondent of the *Railway World* writes that Messrs. Lewis, Bailey, Dalzell & Co., Messrs. Spang, Chalfant & Co., and Messrs. Graff, Bennett & &o., have bought one of the Butler County gas wells, and are arranging to convey the gas in a sixteen inch tube a distance of seventeen miles to their works, to be used instead of coal. They claim that it will enable them to produce iron at a rate that will give them an advantage over all eastern producers.

EXPERIMENTS ON THE MOVEMENT OF AIR IN PNEUMATIC TUBES.

By M. CHARLES BONTEMPS, Engineer in the French Postal Service.

From "The Engineer."

The establishment of the pneumatic system in Paris afforded the author an opportunity of investigating the movement of air in the tubes. For this purpose a system of registration was adopted, electric indicators, connected by wires with chronograph, being placed at intervals along the experimental tube. Each indicator consisted of a box, containing two cams controlled by springs, and a projecting stud. At the spot where the box was attached to the tube, a hole was drilled in the latter, and the box was placed in such a position that the stud entered the hole in the tube, its rounded end projecting slightly beyond the inner surface. The carrier in transit struck the stud, which actuated the cams, and the electric circuit being thereby closed, a mark was made upon the chronograph. This instrument consisted of a train of clockwork giving motion to a cylinder, round which was wrapped a sheet of smoked paper. Parallel to the axis of the cylinder there was a carriage bearing two electric magnets, one in connection with the indicator in the tube, and the other with a second beating electric clock. Each armature was terminated by a fine point, which reproduced on the smoked paper the oscillations of the palette. Motion was given to the carriage by a cord and weight. The carrier, in passing along the tube, closed the circuit on striking the studs, producing a deflection in the straight line traced by one point on the smoked paper. The other point produced a regular indented line parallel to the former, each indentation representing one second. These lines alternated with one another. As soon as the observation was taken the smoked paper was removed, and the surface was fixed by placing it in a solution of gum. The moment of commencing the experiment was electrically noted by a commutator attached to the cock between the reservoir and the tube.

The experimental tube had a total length of 6704 ft. 8 in. It was made of wrought iron 2.52 in. in diameter, in lengths of 16 ft., $4\frac{3}{4}$ in., and connected the central station at Rue de Grenelle, St. Germain, with that of the Place du Theatre Français. It was practically level, with a few curves of large radius; and was laid partly in the ground, partly in subways.

Five indicators were employed ; their positions, distances from the Rue de Grenelle, and the periods occupied in the transit of the carriers, &c., being as follows :

	0	1	2	3	4	5
Name of Station	Terminal Station, Rue de Grenelle.	Cellar, Rue de Grenelle.	Solferino, No. 1.	Solferino, No. 2.	Rue de Rivoli.	Theatre Français.
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Distances from Commencement	0	215 $6\frac{5}{8}$	1659 8	2628 $3\frac{15}{16}$	5413 $1\frac{1}{4}$	6704 8
Distances between two Indicators	0	215 $6\frac{5}{8}$	1444 $2\frac{1}{16}$	968 $9\frac{1}{16}$	2784 $9\frac{1}{4}$	1291 $5\frac{1}{16}$
Times of transit	0	2.3 secs.	30 secs.	57 secs.	136 secs.	167 secs.
Time between two Indicators	0	2.3 secs.	27.7 secs.	27 secs.	79 secs.	31 secs.
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Mean speed per second	0	91 $10\frac{3}{8}$	49 $2\frac{9}{16}$	35 $7\frac{1}{8}$	35 $1\frac{1}{4}$	42 8

The experiments showed that at the moment when transmission commenced the gauge index first fell, and then rose till it reached a fixed point, always low-

er than the initial pressure. Also that the speed of the carrier gradually reached a uniform rate, the slight increase at the end of the journey having been due to a secondary cause not affecting the result obtained.

In other experiments the action of two carriers having a common movement in the tube was examined. The first carrier was stopped in the tube, after a transit of six seconds ; the second was then despatched, and from the period of contact of each with the studs, the following data were obtained :

Position of Indicator.	Passage of 1st Carrier.	Passage of 2d Carrier.
	Secs.	Secs.
0. Rue de Grenelle..	——	0
1. Cellar " ..	——	2.5
2. Solferino No. 1..	26.5	32.0
3. Solferino No. 2..	54.0	60.3
4. Rue de Rivoli ...	133.5	139.5
5. Theatre Français	165.5	171.25

From these figures the author deduced: 1. That the time occupied by each piston in traversing the interval between two successive indicators closely approximated, which showed that the two pistons required similar periods to traverse similar distances. 2. That two pistons which had acquired their normal distance apart, preserved it throughout the whole journey. 3. That the progress of the carrier last introduced was independent of the initial position of the first. From No. 2 it followed that the density of the air was constant from the commencement to the end of the journey as soon as uniform movement in the tube was established.

The periods required by the carriers to traverse the tube between two indications, with different pressures, were as follows :

From Rue de Grenelle to	1. Pressure. 19.685 in.	2. Pressure. 17.716 in.	3. Pressure. 14.960 in.
	Secs.	Secs.	Secs.
Solferino, No. 2...	57	$62\frac{1}{5}$	73
Theatre Français..	167	$178\frac{1}{5}$	208

The respective periods of contact with each indicator were 2.9 secs., 2.8 secs., and 2.9 secs. This practical identity was not accidental, but followed the general law, that the ratio of the periods of transit over two equal distances chosen arbitrarily on the line was, in the uniform period state, independent of the pressures.

BRITISH ALKALI ACTS—ELEVENTH ANNUAL REPORT BY THE INSPECTOR.

The Alkali Act of 1863, after eleven years of solitary struggle with noxious gases, receives assistance from the Act of 1874, and now begins in a small degree a more vigilant, and it is to be hoped a more useful life.

I have little to do but to sum up the work of the past, and I have already done so much towards this that the summary must be short. It is such a frequent question in my mind, what is the Act doing for the good of the public? and, I may add, what are the inspectors doing? that I ought to have the replies ready ; but I doubt if it is quite possible to make them with full satisfaction to all. If it is asked whether we have done the work set us to do, then I answer by the reports that we have done so ; but if it be asked whether we have caused vegetation to rise up where it was not before, if we have produced or allowed to be produced fruit where fruit would not previously grow, then I am afraid we must answer, No. If, however, we are asked whether we have prevented the destruction of vegetation where otherwise it would have been destroyed, then we may safely answer, Yes. It was not our duty to cause crops to

grow, it was our duty to cause the works under our charge to send out not more than five per cent. of muriatic acid. This certainly has been accomplished in the full sense. Gas has occasionally escaped from nearly every work to too great an extent for a short time, but it has been stopped, and the consequence is that the great torrents which at one time rolled over the country are not now to be found. This sounds very well, but vegetation is destroyed without torrents. A gentle flow from a chimney or other part of a work may scarcely annoy us much, and yet in time it may cause destruction to trees and to all perennial plants; whilst a little more, causing still only occasional inconvenience, may destroy annuals and obliterate grass. We must then, in order to obtain a flourishing vegetation, avoid even small portions of gas; and the question remains, how small is the smallest amount in the air that will do injury. It is not safe to allow even as much of sulphur gases as we have in Manchester and similar large towns if we consider vegetation alone.

If more is allowed, then trees disappear. In these small quantities the effects of sulphurous acid and sulphuric will probably be nearly the same. Different opinions are given on this subject. My opinion is that sulphuric acid does most harm at once, but it may be that in the long run there may be more harm done by sulphurous acid first by acting as a deoxydizer, and next by acting, if we may so speak, as sulphuric acid into which it is converted. Of this, however, I know no evidence; but the perception of sulphurous acid being keener and more immediate may favor the supposition, and a not uncommon belief that it does more harm may be founded on better evidence than I can find for myself.

Allowing for the time that when the quantities are small the relative activities of the gases approach each other, I am inclined to go back to a proposal made some time ago in a former report, that the condition of the air of a place ought to be estimated before allowing a chemical work to be established.

If an atmosphere is made to contain 1,000 grains of sulphuric acid per million cubic feet when there are ten works in the community, say in half a square mile or any other space, it cannot be expected to contain air of the same amount of purity when there are eleven works in the space, unless the eleventh work gives out no emanation whatever. But if this absolute purity is not found in the ten, why should it be expected in the eleventh? The expectation is simply irrational; and as places increase in manufacturing industry the air becomes less pure unless the processes are improved. If the processes do not improve the community must either prevent increase or suffer more inconvenience by increase.

This reasoning is childishly simple, but it is not the less needful to write it down, since the complaints continually increase with the increase of works, and the increase of works is not only permitted, but for national as well as private purposes desired.

We have not yet looked the matter with the greatest fullnes in the face. If we are determined to keep towns to a certain standard of purity we must make the standard: if we keep only the works themselves to a standard, then the number of works must not increase, for then the relation of the air of the town to the standard would be altered. It has been shown, as I believe, in my reports, that a chemical standard may with great ease be obtained, but it is one which the community does not fully appreciate, and it is left in the hands of few; but there is one standard known to all, and that is vegetation. This is the most watchful of all inspectors, and the most accurate, and it only requires to be brought into scientific order to be made suitable for constant reference.

It may be taken for granted that where trees flourish, there also man is uninjured by acids such as are given out by chemical works. I say it may be taken for granted at present, but it is only because we know little, and it may be that the influences are hurtful to some extent to men whenever trees suffer. But this we know, that trees may die in an atmosphere tainted by the acids alluded to when men generally are not sensible of inconvenience. The effect on vegetation, therefore, is more striking than upon human beings. The

number of circumstances that influence the death rate is great.

However, I wish to say that we have the matter in our hands; we can estimate the condition of an atmosphere in its relation to acids by the vegetation, but we can estimate it also by chemical methods: and if we allow it to go out of order we must not only blame the works, but ourselves who allowed the works; and if we cannot prevent them we must either submit or fix the standard for them. The standard for the works is not of so much importance as the standard for the district, so that at present our acts are in a very infantile state. It is little matter how much is given out by any work if the district is not injured, and it might happen, when the work was small, that a great proportion would be after all a trifle, but when many works exist a small proportion would of itself be a great evil. I have reasoned more or less in this way repeatedly, but I know that we are not quite ready for legislation embodying all these ideas, we shall probably be prepared before that time comes when our works decay, and the desire to keep them in order shall give way to the hope of keeping them in existence. The progress of the community and of chemical manufactures must go on together, and it may be considered certain that prosperity will endure more pressure, since prosperous men are more ready to complain and more able also to remove cause of complaint.

The results of inspection of No. 1 District as sent by Mr. Fletcher are very satisfactory, although there have been considerable complaints. The works are in many cases unfortunately situated in relation to trees and pleasure grounds, and it is difficult to say what the result of the increased power of attention will be. However, if the manufactures increase in numbers and in magnitude as they have done, it will perhaps not be possible to do more than to keep pace with them and prevent more mischief. I hope this state will be reached. If there should be a difficulty, the great question, who gains most, the community or the individual, will to a certainty be settled by the greater power, but in doing this the rights of the smaller cannot be forgotten. I need not repeat what I have before said on damages.

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Some successful efforts have lately been made in St. Helen's to improve the appliances for condensing muriatic acid, and preventing its escape. The principal are Mr. Gamble's salt-cake furnace, the introduction of thin glass pipes for the conveyance of hot acid gases, and the use of improved hoods over the charging doors of salt-cake furnaces.

Mr. Gamble's salt-cake furnace is a close roaster or muffle furnace heated by gas, and so arranged that the pressure in the combustion spaces is greater than that inside the muffle or inner chamber where the salt-cake is roasted. The consequence of this is, that if there are any cracks or leaky places, either in the middle arch or in the bed, the passage of air is not from the roasting bed into the fire flues and thence to the chimney, but from the fire flues to the roasting bed and thence to the muriatic acid condensers. By careful adjustment of the damper in the flue leading to the chimney the pressures on the inside and on the outside of the middle arch can be made so nearly equal that there is very little passage of gas in either direction, even if the brickwork is somewhat leaky. This increased pressure in the combustion chambers of the furnace is kept up by admitting the gas under pressure from a "producer" as commonly constructed, and by admitting the air necessary for its combustion through a nest of vertical iron pipes nine feet long. These are warmed by the waste heat from the furnace. In this way a saving of heat is effected, and the ascending force of a nine-feet column of hot air is gained.

Mr. Gamble has erected three of these furnaces; one of them has been at work for two years, and has required no repairs during that time.

The expense of fuel is said to be the same as in the case of a close furnace fired direct.

The thin glass pipes for conveying hot muriatic acid gas have been well tried in St. Helen's, and show many advantages over the earthenware ones, in that they do not crack so readily with the heat, and cool the gases more effectually. They have been used for conveying gas

both from the decomposing pots and from the close roasters.

One range that has been at work for many months, was exposed during the winter to both snow and rain, there was no roof over it. Experiments have been made to ascertain the rate of cooling per yard of pipe. Two ranges of pipes each 100 yards long were examined, the temperature at the hot end was 310°, that at the cooler end 134° Fahrenheit, showing that the cooling went on at the rate of 0.59° Fahrenheit per foot. This would depend on the quantity of gas passing, of course. The temperature of the day was 45°. The quantity of acid condensing in the pipes was not great, when however a fine jet of water was introduced at the hot end, two-thirds of the acid was condensed."

Mr. Kynaston of St. Helen's says: "My experience with the glass pipes for the conveyance of hydrochloric acid has been very satisfactory. We use them for the conveyance of both pot and roaster gas from close furnaces, and they will stand the alternations of heating and cooling better than any earthenware pipes we have tried, whilst their cost is not greater per yard than earthenware pipes of the best quality. We have now at work several lengths of pipe which have been in almost constant use since May last. I believe that glass pipes will be eventually used to the exclusion of all others for the horizontal portion of the range for conveying muriatic acid from close furnaces."

Mr. Hazlehurst has not had so much experience with them, but has the same opinion, mentioning that the fixing must be made carefully to prevent breakage. My own observations are most favorable to them, and as every chemist, and we may say every person knows, glass will not allow the passage of fumes; and when earthenware pipes are found fuming along the whole length, these glass pipes are found without a trace of gas around them. The junctions, however, may leak exactly as the junctions of the other pipes. These junctions can be cured when the pipes themselves cannot.

Hoods—At the Bridgewater works St. Helen's, large wooden hoods have been erected over the charging doors of the salt-cake furnaces. A flue leads from the top of the hood to a smoke culvert, so that any escaping vapor is drawn to the chimney. These hoods are much larger than those which have been used before, they measure 14 feet by 7 feet at the bottom, and are 18 feet high. The flue to draw off the vapor from the point of the conical hood is 18 inches square. They answer the purpose much better than the smaller hoods which have hitherto been tried, and keep the sheds very free from muriatic acid gas. The quantity of acid which rises from a charge of salt-cake is however very small when spoken of as a per-centage of that originally contained in the salt. Since the erection of these hoods Mr. Fletcher has measured it, and found it to be on one occasion $\frac{1}{100}$ of one per cent., at another time it was $\frac{1}{90}$ of a per cent.

Hoods hitherto have been of little value for want simply of magnitude, and we must thank Mr. Leather for this improvement. His hoods have one fault, but it is more of principle than practice. The draught from the hoods is into the chimney, it would be better into the condenser. The current however of gas is so small that it does not affect the chimney perceptibly, although it would be disagreeable to those standing near at the time of its escape from the furnace into the air at the usual level of the human head.

ESTIMATION OF NITRIC ACID.

The removal of the acids from the air before it escapes from the chambers, is of the highest importance to the manufacture, and it is equally so to the public. The use of Gay Lussac's tower and other precautions seem to retain the nitrous fumes to an extent which in many cases must be called quite as much as can be desired. The best mode of estimating the escape has been considered, and many experiments tried. A list follows of results after collecting in water and in bi-chromate of potash. When the amounts are small these methods may be sufficient, and if taken out by the flexible aspirator and skaken along with the solution, there is no important loss, otherwise it is appreciable; and when the density of the fumes is great, the loss is also great, and such as would render the analyses of little value.

The method which hitherto has proved itself the most rapid is by the use of peroxyde of hydrogen.

When red nitrous fumes are passed into it they disappear at once, care being taken that the amount of peroxyde is sufficient, and the speed of passage not too great. If the amount should be very great, the use of the flexible aspirator, and of shaking, a method so frequently spoken of, finishes the process of absorption in a few seconds. Permanganates will act also, but they introduce colored bodies.

When the amount of nitrous gases is examined in this way, the estimation is the same of course as for nitric acid, in other words the oxydes are converted into the higher oxyde. I have no results from works by the peroxyde of hydrogen process.

It is important to have a ready mode of deciding the amount of this acid, and many have been tried. It is necessary for us that the manipulation should not be great The indigo process I had given up as a failure in very early days, but it was again tried at the wish of my assistant, Mr. Gillespie, with the following results. The presence of organic matter destroys all confidence, and in chimneys there is usually sufficient from the coal.

The nitric acid was reduced by means of zinc and sulphuric acid ; the sulphuric acid, diluted, was added in portions at a time, so that a brisk evolution of hydrogen was given off for about two hours. The ammonia formed was determined by Nessler's solution, without distillation, after making a portion of the acid liquid somewhat alkaline with caustic soda, and removing the precipitated zinc oxyde. The amount of ammonia in the re-agents used must be taken into account by making a blank experiment with them.

This may be a satisfactory process for rapid work, but it is not exact. When great exactness is required the ammonia must be distilled. An alkaline process, such as the Schulze-Wanklyn method, with aluminum is capable of wonderful refinement, but takes longer time than the above.

The oxydes of nitrogen between the dioxyde and nitric acid oxydize sulphurous acid rapidly, nitric acid does not; indeed in some cases it appears to preserve sulphurous acid.

APPARATUS FOR CONDENSATION.

It is perhaps time for us to have some new ideas regarding condensation, and I expected this year to report some progress that might be important. There are, however, a few indications to be given of the character of the progress attempted that may be of value. The patent of Messrs. Newall and Bowman has been alluded to, and I should have described it more fully had it been carried out to its full extent. Instead of high tanks, the owners employ low chambers filled with a fine spray of water or weak acid ; when the gas is cooled to a certain extent it passes through tubes from the first to the second chamber as in the plan. The advantage of this is the great exposure to the air and the rapid cooling, as well as the rapid admixture of the gas with water. I hope soon to have a thorough account of its results, but I said so on a previous occasion.

The first act will be to generate heat as usual, the thorough cooling in one vessel could not be attained with sufficient rapidity without adding more water than is desired, for this reason some of the gas is passed into a second vessel, becoming cooled partly on the way, and is subjected to another spray. The final act seems best performed in a condenser filled with coke, bricks, or some substances which expose a large surface, the last form of the vapor seeming to require this agency as chemists well know.

The cooling of the gases presents many advantages. We then have only the heat of combination with water to deal with, and that is not subject to variations except so far as the acid varies in the amount of water, but the variation will be very regular. Another idea, however, is that it may be better to add the water of condensation to the warm gases, because then more heat will be generated at a time and the greater the amount of heat the more rapid will be the cooling. The objection to this may be that a high heat will weaken the acid, sending off a large portion of gas to be added to water at another stage ; if however, only a portion of the water were added at a time the great heat would not be attained. This latter method would seem to be the idea carried out in the plans shown. If the heat could be got rid of in tubes instead

of in towers or cisterns the speed would be still greater, and the use of tubes seems to be the favorite method adopted when the Hargreave's process of decomposing salt is employed. This process consists in decomposing common salt by means of the sulphurous acid direct from the sulphur kilns or burners, along with a certain amount of air and vapor of water. The heat is great as the whole of that caused by the combustion of the sulphur and iron of the iron pyrites, as well as that of combination must pass together through the condensing apparatus. This large amount of heat has caused a demand for more cooling, and this is found to be attained by numerous tubes. I have obtained a photograph of those at the Runcorn Soap and Alkali works. There are two long stone cisterns connected by 18 sets of tubes, each set going up and down five times, so that the cooling surface is very large indeed. The gases go finally through the standing tower. In order to assist the gases through this long series a Root's blower is used which works in the acid at a heat high enough to prevent its destruction or at least its rapid wear. The length of cooling pipes used in the manufacture of acid generally, may be said to be constantly increasing, and although I have mentioned this system of pipes in connection with the Hargreave's process, I must not forget that one set has been in action some years at Mr. Gamble's and one at the Netham works, having been erected by Mr. Philip Worsley, for the ordinary purpose of condensation where common salt is decomposed.

A plan by J. Mather has lately been proposed ; it consists of a series of troughs. Air which has been compressed, and then I suppose allowed to cool to the ordinary temperature of the atmosphere, is driven in by the tubes marked H. At the same time it raises the water or weak acid into fine spray, as it is driven in by violence. The apparatus is said to be used either vertically or horizontally. I do not sufficiently know the amount of pressure and its influence, as the apparatus is not in use, so as to be able to judge of the cooling on one hand and the resistance on the other, but, so far as I know, the idea of sending in cold so as to absorb at once the heat of combination is a novel one, and its success must entirely depend on the price of cold. I have made inquiries into this subject, but the question seems still unsettled which is the best cooling apparatus. So far, however, as I can find, the cooling by expansion does not promise to be cheap. The range from the ordinary temperature to boiling, say 60 to 212 is 152° F., or from 15°.5 to 100° C. is 84.5, whilst the range from 60 F. to freezing, or 15°.5 to freezing including the latent heat is 170° or 95° C. It will therefore take not far from a ton of ice to absorb the heat required to raise the same amount of water to boiling. The manufacture of nearly a ton of ice, or its equivalent in cold, so to speak, by the expanding engine would be a rather troublesome process if as I suppose something like half the heat of combination must be got rid of artificially. Even that is enough from a ton of salt to raise the temperature of a ton and a half of water from 60 to boiling. There is also the heat of the gas besides. It may also be remembered that increase of air is not in favor of condensation of gases for mechanical reasons.

As to cooling before condensation, a great deal has been said on this point. I must mention a plan by Mr. Steele at Runcorn ; he passes the tubes through a cistern of water and the rapidity of cooling is great. It is found that 24 feet lower the temperature of the gas of one furnace from 478° F. to 362° or 116° F. = 64.4° C., or 4.5° F., or 2.8° C. per foot.

There can be no doubt that cooling is best effected in narrow vessels or channels, with large external surfaces in proportion to the capacity, but when I bring forward these facts, I do not at all mean to say that the towers have failed. Indeed, I know no better condensation than is made quietly in one tower for a pan and furnace, but the work done is not excessive and the cooling of the tower is therefore sufficient. An increase in the quantity, efficiency, or rapidity of the work demands new appliances.

Let us take an example of actual condensation with ordinary towers. In a work at St. Helens 11 cwt. of salt are used every two hours = 132 cwt. in 24 hours, and containing, as it is not quite pure, 57.7 per cent. in 76.164 cwt. of

dry HCl=253.88 cwt. or 12.694 tons of acid of 30 per cent. and 1.155 specific gravity.

A stone tank is near the pan and roaster, into which some acid falls at 46° C.; about ⅓rd cubic foot of 1.42 specific gravity, when cool is found here. It is very impure. No. 2 tank contains 48.1 cubic feet of acid of 31 per cent. and 32° C., or 1.543 tons.

The tower is reached by acid gas of 60° C. or 140° F., and from it, after water of the ordinary temperature is supplied, there are about 400 cubic feet of acid of 29 per cent. and of a temperature of 54.5° C.

It is seen that even if the temperature is reduced to 60° C. the amount condensed without adding water is only one-eighth of the whole, and the temperature must rise in the tower higher than 54.5°, but how much in the centre is not clear, probably only a few degrees above the issuing acid.

The gases were found to contain grains in a cubic foot—

			Grammes per C. Met.	
	Water.	Acid.	Water.	Acid.
From the pot	484.72	660.69	1109.27	1511.9
From the roaster	19.38	133.07	44.35	304.5
From the outlet to tower	22.66	128.20	51.86	293.4

In another experiment :

	Water.	Hydrochloric acid.		
From the pot	63.80	56.66	146.00	129.66
From the roaster	.64	28.60	1.46	65.45
From the outlet to tower	7.10	16.53	16.25	37.83
Temperature of gas from pot		180° C.		
Temperature of gas from furnace		315° C.		
Temperature of gas from entering tower		60° C.		

It is clear that the smallness of the condensation is not due to the want of cooling only, if at all, but to the want of water. The roaster vapor in the first experiment has only 12.6 per cent. of water vapor instead of 70, and the outlet has almost the same, viz. 15 per cent. The supply of water is given in the tower, and the heat of combination and condensation are envolved there. We should expect every experiment to differ according to the state of the charge.

This points to modes of condensing alluded to where the large tower which does not so easily part with its heat is displaced by small vessels.

One may believe it quite possible to get rid of the heat of combination much earlier by still smaller vessels than any one uses, and more frequent supply of water, or one may suppose only the tubes to be used and supplied at frequent intervals with moisture. In some such direction we must seek for condensation in a shorter space and in a more inexpensive as well as effective manner.

At the same time it must be confessed that the success is not to be had in a moment. It will be seen that the amount of water along with the gas is not quite regular ; this might be got over as it is always small, and must be from the very nature of the usual process. The tower in its capacious interior equalizes all by holding water and gas for some time together, and it would seem that a tower must finish the process so far as we know. This irregularity and consequent difficulties do not occur with the Hargreaves process.

EFFECT OF ACID VAPORS ON HEALTH.

In my last report I gave a chapter on the effect of gases from alkali works on human health, and after saying that the information was meagre but all I could find, I came to the conclusion, sufficiently temperate in expression.

"I should infer from this that zymotic diseases and lung diseases are not removed by the gases of chemical works, but that none of the places exposed to them are so much affected (*i.e.*, by these diseases) as the dense parts of the cities."

The general conclusion is that gases from chemical works are hurtful to the health, but are neither the worst causes as some have supposed on the one hand, nor are they the disinfecting or curative agents which some have supposed on the other.

I shall not go into details of objections to my conclusions because I think this is not a proper place to maintain public discussions, and so little bigotry have I in the matter, that I do not care if I am proved to be wrong by a large amount of information than I have obtained. I should by no means think this a disgrace, because the subject cannot be begun with correct conclusions but must gradually unfold itself, probably with many rises and falls. I grant that it may be wrong to draw any very decided inference from the statistics of South Shields, unless manipulated with great exactness. This process, however, produces in itself frequent uncertainties and suspicions, and I do not enter upon it. I can, however, readily believe that the population of a seaport is exceedingly difficult to bring under exact rule. With the full belief that I shall again be held as bringing out meagre statistics, I shall produce some from a district of all others most exposed to the fumes from alkali works.

Deaths in 1,000 Deaths at Widnes for Five Years ending September 12th, 1873, and in all England 1869–1872.

	Widnes.		England.			
	Five Years.	In 1872.	1872.	1869.	1870.	1871.
Phthisis	64.46	65	107.619	106.422	106.106	104.481
Bronchitis	78.62	53	87.489	89.346	91.369	93 342
Laryngitis	6.3	6	3.135	3.374	3.405	3.191
Pneumonia	95.12	100	41.505	51.401	46.427	44.567
Asthma	0.23	6	6.100	7.541	7.619	6.884
Lung disease	15.70	9	9.964	10.009	9.959	10.359
Scarlet fever and scarlatina	61.29	59	24.397	56.279	63.672	36.344
Whooping cough	14.94	15	28.253	22.327	23.285	20.279
Small-pox	4.72	9.4	39.074	3.186	5.126	45.268
Total	335.71	322.4	317.536	349.885	356.968	364.715

Now I do not care to draw conclusions wholesale, but two points strike me as interesting. 1st. That bronchitis cannot be considered high, being less than in 1872 for all England, which year had not a very large amount. 2d. That scarlet fever, which gases might be supposed to disinfect, is very high whilst whooping cough, which the gases when strong are supposed to cure, is low. As to the general health I do not think five years of such a population as that of Widnes to be a standard for reasoning from ; it is frequently changing ; there are many young people moving to it for work, or leaving when work is slack, and one can best judge from the character of the complaints incident to the place from those diseases which attack people who are not mere weaklings.

I ought not to forget that my colleagues, inspectors for the separate district, have a right to have their opinions recorded. Mr. Fletcher tells me that about two years after the passing of the Act, two proprietors, or their agents, showed him trees that had been marked for felling, but from their revivel were retained, and in one of the districts at least are now flourishing. He mentions also a large estate which he considers to have been saved by the Act, and it certainly is my opinion that the trees must have gone to destruction long ago had the Act not existed, even without the increase of works, but most certainly with it. Mr. Fletcher says also that the farmers round St. Helens have not complained of muriatic acid lately, but the chief complaints have been caused by sulphuretted hydrogen. I am not disposed to speak quite so favorably as he does to acid, but on one point I fully agree, that " people have forgotten how bad it was before the passing of the Act of 1863."

This Report takes no notice of anything done under the Act of 1874. That Act has caused several fresh plans to grow up; some only have been alluded to. A plan for drawing all the gases from close roasters through a condensing system with lime to finish with, a fan being the agent at the extremity, and quite free from any of the gases, is one that I am desirous of seeing tried.

THE SALTPETRE DEPOSITS OF PERU.

From "Journal of the Society of Arts."

The country wherein lies the industry I propose to describe in this paper, is situated on the West Coast of South America, and belongs to that part known as the Costa Seca or Dry Coast, being the slip of land comprised between the 4th and 40th degrees S. latitude, and which, measured from the River Tumbez, the Southern boundary of the republic of Equador, to Valdivia in Chile, embraces, within a length of over 2,400 miles, the entire seaboard of Peru, Bolivia, and part of Chile. Over this considerable extent of sea coast no rain falls to modify the parched appearance of the soil, and no humidity is obtained from the heavens beyond that acquired from the condensation of the fogs which envelope the coast during the winter months. With the rare exception of a shower of rain occurring once or twice in the year, the cultivator is dependent upon the scanty supply of water afforded by the rivers which derive their origin from the rains and snows which fall but moderately on the western slopes of the lofty Cordilleras. Thus the coast can be briefly described as consisting of a succession of valleys of great fertility, separated by arid wastes of high ground of immense extent.

The section with which I am at present dealing lies at the southern extremity of Peru, and though saltpetre exists in small quantities in Bolivia, up to now it has only been worked in the former country, in the province of Tarapacca, perhaps more familiarly known as the district lying inland of the ports of Patillos, Iquique, Mexillones, and Pisagua. The coast between these ports presents seawards a precipitous front, with its cliffs rising to a height of from 1,000 to 3,000 feet from the water. These cliffs have but little slope; therefore, all road approaches are traced in a diagonal direction upon their face, or ascended by a series of reversing inclined planes, of exceeding steepness, and perilous to the mules performing the transport service.

From the summit of the coast cliffs the land rises with nearly an uniform ascent, proving to be, by the construction of the Iquique and La Noria Railway, after deducting for the deviations of the latter, a general inclination of 50′ until it reaches an elevated plateau known by the name of Pampa de Tamarugal. This pampa, or extensive plain, is situated at an elevation of 3,440 feet on its western side, and, extending southwards and northwards, measures about 300 miles in length, and from 30 to 60 miles in breadth. The surface is perfectly smooth, and appears level to the eye, but in reality it rises slightly in an easterly direction towards the Cordillera. Its surface is covered in some places by a cap of alluvial soil, but more generally consists of a finely granulated sand, which is raised by the slightest breath, and by a heavy wind is carried over the plains in broad thick clouds, which obscure the horizon, and bilnd the traveler with their dust. On still days curious conical-shaped clouds, resembling water-spouts, may be seen rising up in all parts of the plain, produced no doubt by the rotary motion which must occur at the meeting of two opposing currents of air. Then a tremulous motion is observed when the eye scans the horizon, and this is caused by the ascent and descent at one and the same time of layers of air at different temperatures—the cool coming down, the warm going up. At different points the horizon is broken by patches of tree; these trees are called "algarovas," and their wood is hard and

brown, not unlike English oak. They seldom grow in this locality to any considerable height. The deposit of roots belonging to this tree, to be found nearly all over the pampa, indicate the existence in former days of an immense forest, and the traditions of the place explain that formerly wood was the only fuel used in the reduction of the saltpetre and other minerals in which the province abounds. The algarova requires but little moisture, and subsists on the humidity which it absorbs from the atmosphere.

The mineral containing saltpetre is called "caliche." Caliche generally lies at depths of from one to ten yards below the surface, and sometimes resembles in appearance loaf sugar, and at others rock sulphur; and again it appears white, crossed with bluish veins. Its gravity varies from that of common salt to sandstone (2.41 average), according to the amount and nature of earthy matters it may be allied with. The nitrate portion dissolves freely in boiling water, leaving behind as a residuum the earthy substances. The custom is to boil it at a temperature of from 220 to 240 degrees Fahrenheit. This valuable mineral is found beneath a covering of calcareous earth, generally assuming the appearance of half-formed sandstone, when it is serviceable for building purposes. A shaft, or hole, sufficiently wide to permit of the passage of a man, is sunk through this cap as far as the under side of the caliche, at which point the underlying earth is dug out in a circle for several feet. The chamber thus formed is charged with gunpowder (manufactured in the district), and on being fired the result is to disengage and throw up to the surface the subterranean caliche, which is picked out by hand and stacked up in heaps at some convenient point, whence it is conveyed in carts, capable of holding about a couple of tons, to the "oficina," or manufactory. Considerable skill is required in selecting the points where to begin mining operations, and it frequently occurs that large sums of money are paid for lands which on being worked prove to be worthless, either on account of the scarcity of the caliche, its bad quality, or its great depth beneath the surface. These losses are sustained on account of the difficulty sometimes experienced of obtaining labor or tools in a country so inhospitable in its resources, and possessing no real indigenous population.

At the manufactory the caliche is broken up, either by hand labor or by steam crushers, into cubes capable of passing through a 1½ inch ring. Blake's patent crusher, manufactured by Messrs. Marsden, of Leeds, has of late years been used in several manufactories, and would, I have no doubt, be more generally employed for this purpose, were the body of the machine made in sections to facilitate its transport, instead of being in one massive block weighing several tons.

In the old method of extracting the nitrate from the caliche, the broken caliche is shoveled into the boiling pan, which is placed over a fire. After from six to eight hours' boiling in a liquid composed of fresh water and the liquid remainder of a former boil—called *aqua vieja*, or "old water"—the nitrate of the caliche is dissolved and forms part of the solution, which by means of a ladle is transferred to a pan, where it deposits its nitrate. In this process the caliche is boiled at a low temperature, and the salt is supposed to remain in the refuse. Great waste attends the operation of dissolving at a low temperature, which can not well be avoided by using the direct fire employed at the *paradas*, and it is estimated that in some cases some 30 per cent. of nitrate is thrown away with the refuse, or, as it is called there, *ripia*. The water is lifted up from wells in buckets attached to ropes working round a drum, which is placed on a vertical shaft and made to revolve by a mule drawing round its circumference. Thus no steam power is employed in this process. The increasing demand for nitrate caused the introduction of improved plant for its elaboration, and now all the important manufactories are worked by steam-power.

The improved form of *cachucha*, or boiling-tank, is either opened or closed, and the heating agency is steam, introduced at the bottom of the tank by means of a steam-coil. The coil is usually placed beneath a perforated false bottom, thereby allowing the heated vapor to circulate through the caliche lying immediately above. Sometimes an

additional coil is run directly through the caliche.

Great diversity of opinion exists among saltpetre manufacturers upon the most economical form of cachucha. Some advocate the closed cachucha, which in every respect may be compared to a steam chest, because they maintain that, the steam being enclosed, there is no waste of heat, and consequently an economy is effected in coal. Their opponents assert that the steam in the cachucha condenses, and thereby weakens the solution, and that it prevents a most important operation—the stirring up of the matter during the boiling. On the other hand, the open cachucha allows the steam which has passed through the caliche, and done its duty, to escape into the air, and enables the attendants, during the entire boiling, to constantly turn over the caliche, thereby enabling the heat to penetrate into every crevice of the mass. The result is to extract more nitrate from the caliche, and less is thrown away in the ripia; hence, by this latter system, an economy is effected in caliche, which more than balances the extra consumption of fuel.

In the closed cachucha the caliche is first placed in boxes made of perforated iron plating, which are mounted on wheels, and are pushed along a tramway into the cachucha. To overcome the difficulty of stirring up the mass, boxes have been made of a circular shape, and capable of revolving on their standards when locked to an axle when worked by a wheel on the outside. This plan, however, proved a failure, on account of the accumulation of insoluble matter at the bottom of the cachucha, which completely wedged in the boxes, and the attempt to give the latter a rotary motion could only have been done at the risk of breaking the couplings and damaging the boxes themselves. This plan might be carried out by making the plant stronger, and by allowing adequate space for the insoluble matter which escapes from the boxes; but then that would be objectionable, on account of the large steam space it would afford in the cachucha, and the consequent impoverishment of the solution through the condensation of the steam.

There are other forms, known as egg-shaped cachuchas, owing to their similarity in form to an egg placed on its smaller end. These offer great facilities in the operation of charging and discharging the material. The caliche is conducted over a road to their upper part, and shot down. After being boiled, the solution is tapped, and the refuse allowed to fall into trucks placed beneath, which convey it to the spoil bank. The chief disadvantage of these cachuchas consists in the necessity of having at command considerable height for the approach road, and consequently they are chiefly used at those places where an adjoining hill affords that height, the manufactory being built at its base. Where no hill is available, the trucks may be raised on an inclined plane.

Chemists interested in the trade have of late been engaged in searching for a method of extracting iodine from caliche, but as the operation is known but to a few, and when known kept a dead secret, the author does not propose to touch further upon this subject.

The labor required for the different operations attendant on the production of nitrate is chiefly supplied by Bolivians. Great numbers of these people annually cross the Cordilleras, taking with them their wives and children, and offer themselves for hire at the saltpetre establishments. They earn from one to two dollars per day, and perform their work well, and they are much esteemed by the manufacturer for their docile disposition and readiness to obey orders. Their migratory habits never allow them to remain long in one locality; they remain perhaps six or twelve months, then leave in a tribe, to go to some adjacent establishment. Chinese coolies are employed at some places, but their feeble strength, and lack of *physique*, render them incapable of performing the hard work of mining, and the rough duties attendant upon this manufacture.

Mechanics, bricklayers, carpenters, and skilled artisans of any description command high wages in this district; and the manufacturers can well afford to pay them highly, as they calculate upon at least 50 per cent. of the wages returning to their pockets, by the sale of provisions and commodities of every description, of which they are the sole purveyors (the truck system).

Below is a copy of the balance-sheet

of the working of an oficina, which may be taken to show a fair average of the profits made in prosperous times by careful management:

March, 1873.

Disbursements.

	Soles.
Elaboration	7,680
Coal, 2,300 quintals, at 1.5 soles	3,450
Mules	800
Provisions	3,000
House and office	1,200
Repairs and loss	600
Gross profit	3,670
	20,400

Entries.

	Soles.
Sale of 14,000 quintals of nitrate, at 1.10 soles per quintal	15,400
Item provisions	5,000
	20,400

In this case the nitrate was delivered at the manufactory, from whence it had to be conveyed to the port by the purchaser, either by rail or by mules.

The cost of conveyance by mule service is fixed according to the distance of the manufactory from the port. Thus from La Noria to Iquique the price is from 5 to 6 reals (Peruvian), and from other oficinas half the distance from the port the price is only half that amount. A good mule will carry three quintals, the usual load is two down to the port, and one-and-a-half up loaded with coal or provisions. Frequently the mules have to perform the journey there and back, some 28 miles each way, without touching water, owing to the total absence of that element in its natural state. For the use of the inhabitants sea water is condensed, but when the machines fail, and there is a scarcity, the price is too high to give drink to the mules; two cents per gallon is the price paid at Iquique for condensed water, and sometimes as much as four is paid.

The construction of the Iquique and La Noria Railway did much to take the transport away from the mules, but it did not entirely succeed in doing so, owing to its inability to convey the enormous quantity of saltpetre daily brought down. The line starts in a northerly direction from the port, making towards the coast-cliffs, which it reaches at a distance of three miles, and at an elevation of some 300 feet. From that point it reverses its direction to the north, and creeps up the hill side on an incline of three per cent. until it attains the summit of the coast-cliffs at the station called Mollo, which is situated at an elevation of 1,630 feet above the sea, and at a distance of ten miles from Iquique.

From thence it follows a general direct course on to La Noria, winding itself round hill sides in curves of from 300 to 500 feet radius, sometimes raising itself high above the surrounding country where the latter dips and assumes the shape of a bowl, over the extreme edge of which the railway must necessarily pass, and at other times penetrating through deep cuttings of irregular porphyritic rocks, clearly indicating the volcanic agency that must have occurred to have caused their displacement, until it reaches the district known as La Noria. Throughout, the railway is of the 4 8½ gauge. Where there were cuttings near, their *debris* supplied the fillings, and at other places trenches were dug at each side of the line. The chief want we experienced was soft earth or sand to pack in the permanent way with, which was very scarce, owing to the hard nature of the surface of the ground.

Though it is not proposed to give in this paper a detailed description of the railway, the points bearing on the transports of saltpetre are set down as follows:

The grades between Iquique and La Noria vary from 3 to 5 per cent, and the up trains generally consist of the following loads:

	Eng. Tons.
One Fairlie locomotive in running order	54
Four American double bogie cars loaded, say 24 tons each	96
One tank holding approximately 2,000 gallons of water and its car, say	22
One employé's car	12
	184

The inequality of the traffic, the up traffic not amounting to a third of the down, necessitates the hauling up of empty cars. Thus trains of from 8 to 10 empties are dispatched. The Fairlie engine has done some good service on this line, where it has shown its superiority over that of the American type. I will

compare the work done with the theoretical duty the Farlies should perform. The average speed up the line is about 10 miles per hour, and loads up to 200 tons, including the engine and water tank, are hauled up inclines of 1 in 22 and even as steep as 1 in 20. Having the diameter of cylinder 15 inches, the stroke 22, and the driving-wheel 42 inches in diameter, and a mean pressure in the cylinders of 100 lbs., the following formula expresses the theoretical tractive force of the engine in lbs :

$\frac{15^2 \times 100 \times 22}{42} = 11{,}785$ lbs. for a single pair of engines, which must be multiplied by 2 for the Fairlies, and which makes 23,570 lbs. total tractive force. The resistance due to gravity would be $\frac{2{,}240}{22} = 102$ lbs. per ton, and that due to friction say 10 lbs. The haulage force of the engine then is found thus :

$$\frac{23{,}570}{102+10} = 213 \text{ tons.}$$

On the downward journey, as many as 20 cars loaded with saltpetre have been lowered by these engines, but as the risk attendant upon the train breaking away is so considerable, the number has been reduced to 15 or 12, representing a total load of some 340 tons. Each car is loaded up to 264 quintals, or nearly 12 English tons, and the bags are laid at each end, immediately over the bogie frames, leaving the middle part of the car empty. The price charged by the late company was 1½ cents per quintal per mile, being the price allowed in the concession from the Government, thus taking the distance of the manufactory from the port, about 33 miles, the cost of conveyance would be five Peruvian reals (equivalent to 10 Spanish) per quintal. From an extract taken from Consul Hutchinson's report on this trade, published in the Foreign-office Blue Book of Consular Reports for 1873, we learn that in eleven months of the year 1872 the total export of nitrate from Iquique was 3,983,798 quintals, or 362,163 per month. Since then it has no doubt increased, but we will take only that amount which would correspond to over 12,000 quintals, conveyed daily to the port. For 120,000 quintals, some 45 cars would be required. Supposing the railway worked for a monopoly of both the up traffic (coal and provisions) and the down traffic, it could only approach such a monopoly with the following train service :

Locomotives running per day.		Cars.
3	trains of provision and fuel cars, 4 cars loaded and one empty.	15
4	trains of 8 empty cars each....	32
2	trains of water tanks to supply the above, 8 tanks each.	
9	Cars.......	47
	Water tanks.....	16

This is only taking the up traffic to be one-fourth of the down ; most probably it would reach as much as one-third, if not more, were the railway to secure a monopoly, then a greater number of trains would be required. The late company never possessed sufficient rolling-stock to attempt anything of this kind, and, in addition, they had, as the present company have, to contend with the water question, which, in the author's opinion, would, were it to remain as at present, entirely prevent their securing a monopoly of the traffic. For working the first section, to Molle, the water is obtained from sea-water cleansed at Iquique, and for working the remainder of the line it is brought from a well in the interior in tanks to Molle, at an enormous cost. Until a proposed scheme for obtaining water from the interior, to be conveyed to the railway stations at Iquique through piping, is carried out, the railway company must continue to work under the great disadvantage enumerated above.

To show the large traffic returns which this important railway might, under certain conditions, earn, it is only necessary to refer to the amount of saltpetre shipped from the port of Iquique, in 1872, which approached 4,000,000 of quintals. The entries would be then, assuming a monopoly :

	Soles.
4,000,000 of quintals, at 5 reals, taken to port...............	2,000,000
Up traffic, consisting of coal, corn, hay, provisions, and material of all descriptions, say one-third of above, 1,333,333, at 5 reals..................	666,666
Total of entries...	2,666,666

Or equivalent to a sum of over 533,333 pounds sterling.

The author refrains to touch upon the working expenses, for fear of acting in opposition to the directors' wishes.

There are at present some 3,000 to 4,000 mules competing with the railway.

This line, as well as that to Pisagua to Sal de Obispo, was constructed by a private firm of Peruvians, Messrs. Montero Brothers, who are the owners of the property, and by whom it was worked until within the last five months.

Whilst dealing with the conveyance of saltpetre to the port, I must not omit to mention an unsuccessful endeavor made by a company to convey down the nitrate in a liquid state through iron piping. The company which entertained this project was called "La Compania Salitera Barrenechea," now, I understand, in liquidation. The objects the promoters proposed to obtain were, firstly, to avoid as much as possible the use of steam in the reduction of the mineral, and thereby secure an economy in coal. Secondly, to save the freight of conveyance by rail or mule to the port. The first was sought (though I never visited the works at the mines), I believe by dissolving the caliche in vertical pans by passing cold water through it, resembling the process of filtration. The solution drawn from the bottom of the pan was pumped up to high ground (for the mines lay in a hollow), whence it ran down by gravitation through piping to the works at the port. At the latter place the solution was boiled in large circular pans, heated by a fire placed so as to spread over the entire bottom of the pan. The result of the first experiment may be easily anticipated. The solution, impregnated with the salts it held in suspension, soon began to precipitate them, and a thick cake of nitrate and salt shortly collected at the bottom of the boilers, which were in consequence burnt, and rendered useless. Notwithstanding the wrong principles upon which the plant was designed, which the directors recognized, and which could have been remedied by an additional expenditure, the company apparently took no steps to modify these evils, and the real cause of their suspending their operations last September was, I understand, the fear they entertained as regards the quality of their lands. With caliche containing a large percentage of common salt no profit is to be made by working it, either with this or another system, though, it must be understood, I do not give any opinion upon the nature of the mines in question.

As regards the extent of land supposed to contain saltpetre, no formal measurement or survey has been made, for frequently land is supposed to contain nitrate which, on being opened, proves to be barren in that mineral.

The lands round about La Noria were those first worked, and there remains very little "virgin land" left in that quarter. There are large spaces however, left untouched on the Pampa di Tamarugal, and nitrate is supposed to exist all along the southern border of the pampa, between the points known as Pozo di Almonte and Sal de Obispo, which are marked upon the map.

Numerous deposits are reported to exist in the south, where some oficinas have been opened, and a railway made to them from the port of Patillos, but for the reasons before stated, namely, for the want of a geological survey, it would be impossible to give any definite opinion as to the area of land containing saltpetre or its quality. Large portions of land in the south are said to contain nothing but beds of common salt.

I observe that Mr. Markham says, in his "Travels in Peru and India," "it is calculated that the nitrate grounds in this district (Tarapaca) cover 50 square leagues, and, allowing 100 pounds weight of nitrate for each square yard, this will give 63,000,000 tons, which at the present rate of consumption will last for 1,393 years." I cannot agree with Mr. Markham that the deposits cover so large an area as 450 square miles, but it might amount to 100, though that can only be a supposition, and no opinion can be made in reference to the quality of the nitrate. The estimate of one quintal to the square yard is too low in my opinion. I found, on having made an analysis of two specimens of caliche, they contained the following substances :

1st Specimen (White).

	Per cent.
Nitrate of soda	48
Common salt	40
Insoluble matters	12
	—100

2D SPECIMEN (YELLOW).

Nitrate of soda	55
Salt	35
Insoluble matters (containing sulphur)	10
	100

The mineral is found in layers of from a few inches to three yards in thickness, and I think three quintals per yard of surface is a fair average for land containing nitrate in sufficient quantities to repay its working. Provided these lands in the south proved to be good, we may in that case assume a total area of 100 square miles; but otherwise, excluding these, it would not be safe to count upon more than one-third of that area, 100 square miles at three quintals per square yard would give 42,240,000 tons, which at a consumption of 3,000,000 quintals per annum would last over three centuries. All these grounds have been claimed under the mining laws of the country by private individuals, and I believe the Government does not possess any of them at the present moment.

I will now describe the physical features of the country upon which are based my suppositions as to the origin of these deposits. Ascending from the sea-board the cuttings in the railway bring to view rocks of porphyritic formation. Granite is seen in a state of decomposition crossed with veins of quartz, and in other places are beds of coal and sandstone. At the summit the railway cuts through a bed of white limestone resembling marble by the polish it will take, and for which rock it has been mistaken by many. To this coast range succeeds the vast plain of Tamarugal with its alluvial coating, and which extends some thirty miles to the foot of the second range of mountains, chiefly composed of sandstone, and among which extinct volcanoes have been recognized. Another level plain intervenes between these latter and the range of mountains known as the Cordillera proper, among which is situated the famos volcano "Isluga."

Returning to the Pampa of Tamarugal, a group of hills, ranging from 200 to 500 feet above its level, borders its western extremity. On the slope of these hills lie the deposits of salpetre, and in no case has that mineral been found on the pampa itself On its eastern side stands the second range of mountains already mentioned. These mountains are pierced at frequent intervals by deep ravines, at the bottom of which small streams find their bed, but the uniform layers of boulders packed up on each side of the ravines leads the imagination to picture the large rivers, which at one time, no doubt, traveled down these channels on their way to water the wooded plains of the pampa. Upon entering the ravine of Tarapacá, two leagues of ground covered with boulders have to be traversed, and a deep gully still can be traced in the neighborhood which points out the course taken by a pre-historic river.

By one of those revolutions in nature, the occurrences of which are proved by the researches of the geologist, the rains ceased to fall with their accustomed abundance, and have left, where formerly were forests and grassy plains, nothing but an immense arid desert. But though the rains are now insufficient to form themselves into rivers, they fall with regularity, and, being absorbed by the earth, they percolate through porous strata, to empty themselves into the natural reservoir beneath the surface of the pampa. Thus water may be seen jetting out in springs at the foot of the eastern range of mountains, where it is obtained in large quantities by the natives, by driving tunnels into the yellow sandstone which forms the foundation of the slope. The crust at this point is chiefly sand and a limestone having a very washed appearance, from which water is also obtained, but it does not repay the working, as it is soon dried out.

At Pica there are two basins supplied with water in this manner, the one placed some fifteen feet above the other. The top one receives from its tunnel supplies of cold water, whilst the bottom receives warm water (90° Fah.). At a point a quarter of a mile up the hill, and (perhaps) at an increased elevation of 100 feet, another basin receives warm water; thus the anomaly is presented of a cold stream running between two hot streams.

Following the section of the pampa westwards for about ten miles, water is found beneath the surface at a depth of three yards. In this latitude a novel kind of cultivation is practised, namely,

the capillary attraction which some plants possess to an inordinate degree is utilized by making them suck up the water through several feet of earth. The upper crust of saliferous sand is cleared away to a depth of some three feet, until the alluvial soil is encountered. A trench is thus formed, measuring fifty feet wide and several hundred feet long, and the excavated material is packed up on its borders. Alfafa, vegetables, and different cereals thrive well in these pits, and the cultivation proved so successful that the Government, who in that country must have a finger in every pie, established an agency to collect rents and to plant a farm on their own account, with the object of supplying the soldiery with vegetables.

At my last visit the Government agent was erecting a windmill destined to raise the water by means of a pump, so as to attempt surface irrigation. Considering the force and constancy of the south-westerly winds, the attempt will most likely prove successful.

Resuming a westerly course at the termination of another eight miles, the water is encountered at a lower depth, namely, at about six or eight yards below the surface, but is still sweet to the taste. Another eight miles in the same direction and the western hills are arrived at, where the water is found only at depths of from 40 to 100 yards, and, with only a few notable exceptions, so strongly impregnated with saliferous matter, that it is unfit for the use of animals. Thus the pampa may be compared to a cup, slightly tilted up at one end and filled with a fluid, the surface of which is depressed from the natural level by the weight of a covering whose depth increases in proportion to its distance from the raised end. This subterranean reservoir is supplied directly from the rainy district, and as a proof of the free connection which exists between itself and its sources, it is only necessary to refer to the fact of the simultaneous rising of the water in the wells almost immediately after the commencement of the rainy season.

Now, taking into consideration the facts above enumerated, the position of the deposits beneath the surface of a lee-shore, the proximity of numerous volcanoes uniting with their lava, probably large quantities of salts, sodas, sulphurs, and other substances, and, lastly, the direct communication maintained by the rivers between the volcanoes and the nitrate grounds, would it not be reasonable to suppose that these deposits derive their origin from volcanic discharge? Is it not probable to suppose the lava discharged during eruptions, and falling into the ravines, was snatched up by the rivers in the latter, and whilst its heavier particles were deposited in the neighborhood, the lighter, consisting of the salts, were conveyed across the desert and thrown upon the opposing shore, which became coated with the deposits on the withdrawing of the waters in the dry season?

With the arrival of the fogs in the winter, this coating of soda would experience rapid liquefaction through the condensation of the fogs, and the product would be absorbed by the porous soil of the formation.

It would seem that no suitable place offered itself for the accumulation of the deposits on the eastern side of the pampa, where they would have been rapidly dissolved, and washed off by the rains, and, indeed, where the hardness of the formation would not have permitted of their percolation.

Bolleart, in his "Antiquities of Peru, &c.," whilst opposing Darwin's opinion, that the pampa was formerly an inland sea, and obtained its salt thereby, says: "As to iodic salts, we need not look for them to the sea, as iodine and bromine exist in the minerals of the regions;" and in another part he hints at the probability of their being derived from volcanic sources.

If Darwin was right, would not the greater part of the pampa be covered with salt on the evaporation of the sea-water? But it is not so, as no beds of salt on the pampa have been discovered after boring for a considerable depth. It lies only on the slopes of the western shore.

The heavy fogs to which I have alluded appear between the months of March and October, and on condensing leave a thin coating of chloride of sodium on projecting rocks and stones, or any impediment which seems to arrest their course.

To bring back to memory the origin of

these sea fogs, I will quote what Captain Maury says about those of Newfoundland, in his "Physical Geology of the Sea," article 166: "The fogs of Newfoundland, which so much endanger navigation in the spring and summer, doubtless owe their existence to the presence, in that cold sea, of immense volumes of warm water, brought by the Gulf Stream." A distinguished scientist, Señor Raimondi, in his "Apuntes sobre la Provincia litoral di Loreto," says at page 7: "The immense extent of sand stretching along the coast of Peru, in some places from 15 to 20 leagues in breadth, has likewise to do with the absence of rain, because, being a good conductor of caloric, the sand, acted upon by the sun, evaporates a current of warm air, which prevents the watery vapors already spoken of from being condensed. In winter time, the atmosphere being of course colder, and the sand, being a better conductor of heat than the water of the sea, becomes colder than the latter, so that its low temperature causes the condensation from which we have the fogs so general in winter time on the coast of Peru."

It appears to me, in addition to this last reason given by Raimondi, that the fogs are caused just in the same manner as those off Newfoundland, with the difference that, in lieu of warm water pouring itself upon cold, the cold water of Humboldt's current, coming from the south Polar regions, mingles with the comparatively warm waters of the Pacific coast, thus producing the same effect. These fogs appear at night time, when frequently the thermometer descends below freezing point, to rise again, at 10 A. M., to 60° Fah., and at noon to 80° Fah. in the shade.

To strengthen the supposition of these deposits having been created through volcanic agency, I will again quote Humboldt; at p. 397 in vol. iii. of his "Travels in South America," he says: "The enormous masses of muriate of soda recently thrown up by Vesuvius; the small veins of that salt which I have often seen traverse the most recently ejected lavas, and of which the origin (by sublimation) appears similar to that of oligist-iron deposited in the same vents; the layers of gem salt and saliferous clay of the trachyte soil of the plains of Peru, and around the volcanoes of the Andes of Quito, are well worthy the attention of geologists who would discuss the origin of formations."

I must mention that the grounds are nearly everywhere covered with flat pieces of clinkstone or phonolite, averaging in size from a few inches to a square foot. A strong opinion is entertained by the natives that these blocks of stone are aerolites. As they belong to the trachytic family, it is probable to suppose their having been washed down from the volcanic mountains, and to account for their being found on the top of hills of moderate height, an upheaval might have occurred subsequently to their being deposited.

If we admit Humboldt's view as regards the sometime disposal of materials discharged from volcanoes, the origin of the saltpetre deposits will have been almost proved to demonstration, for the volcanoes would supply the materials which would be conveyed by the hydraulic agency I have attempted to describe, to the site they now occupy, where, after being dissolved by the fogs—naturally converted into liquid—and absorbed by the earth, in union with nitrogen derived from the atmosphere, they are dug out as nitrate of soda, for the use and to promote the prosperity of man.

The author has abstained in this paper from touching upon the use which is made of nitrate in this and in other countries, for he considers the important position it occupies in various compounds, and its large employment in agriculture, well deserve a special study and the preparation of a second treatise.

THE *Independance Belge* gives some curious statistics relative to the consumption of wood in France. A large quantity of soft wood is used for making toys, and to give an idea of the magnitude of this trade it will be sufficient to take one article alone, children's drums, of which in Paris alone 200,000 are sold every month. The total number made annually in France is estimated at 30,000,000, while a considerable quantity of wood must be consumed to supply 60,000,000 of drumsticks.

EXPERIMENTAL RESEARCHES IN BESSEMER WORK.

By W. MATTIEU WILLIAMS, F.R.A.S., F.C.S.

From "Iron."

In the last number of the *Journal of the Chemical Society* is the following abstract of the observations of F. v. Ehrenwerth :—"In Bessemer steel, obtained by blowing pig-iron rich in silicon, it is remarkable that the greater the amount of silicon present, the harder in general is the steel. It is only in the softest qualities that the silicon disappears, and with it the manganese, for the most part, or entirely. In the selection of these qualities the Eggertz method may therefore be used. But in the case of the hard varieties containing much silicon (after exerting greater influence than the carbon), this method can lead only to errors and inaccuracies in the selection. The manganese and silicon in such a case should eitheir be supposed constant, or be estimated, and a combined scale being set up, the position thereon could be determined. The Eggertz method loses therefore nothing of its value for carbon estimations, or in the selection of varieties of steel in which silicon is not present."

Having made or superintended about fifteen thousand carbon determinations (chiefly in Bessemer steel) by Eggertz's method, and carefully observed the connection between the quantity of carbon thus indicated, and the practical properties of the steel containing it, I venture to state some of the results of this experience, which have satisfied me that many of the objections made to Eggertz method are merely frivolous, and others are entirely baseless.

The above quoted conclusions of von Ehrenwerth belong to neither of these categories, but, on the contrary, appear to be the results of careful practical observation and research.

The reader is probably aware that this method is based on the fact that when steel or cast iron is dissolved in diluted nitric acid (sp. gr. 1.2 is the strength actually used) the solution has a brownish color varying in depth with the quantity of combined carbon in the steel or cast iron ; and that it is carried out by first making a standard solution of cast steel of known composition and comparing to this the color of a similarly made solution of the steel to be examined.

Some have condemned this method because it is less accurate than those which the objectors prefer to use, others that it cannot be applied at all to the determination of very small quantities of carbon, and some chemists have even maintained that it is altogether unreliable and worthless.

Taking the last objection first, it is doubtless true that in unskillful hands it may fail to such an extent as to be practically worthless. A man may be a learned chemist and even a good gravimetric analyst, and yet fail when he first attempts a volumetric and colorimetric determination of this kind. A certain amount of special technical skill, only obtainable by special practice, is necessary, in order to carry out this method expeditiously and satisfactory. Besides this, there is the possibility of partial color-blindness disturbing such determinations. The late Dr. George Wilson found, by repeated experiments, that, on an average, about one in every thirty of the pupils attending his class for chemistry was decidedly blind to certain colors, and that scarcely any of them were aware of the fact until his experiments had demonstrated it. This is necessarily a source of considerable possible misapprehension of all colorimetric determinations ; the "personal equation" is vastly more disturbing here than in the weighing of precipitates and potash bulbs. As the carbon determination is more dependent on light and shade than on tint, color-blindness may not interfere so seriously as in some other cases.

Great care is necessary in order that the conditions of solution shall be the same, both for the standard steel and that to be examined. The acid should be the same, and free from chlorine, the temperature the same, both during solution and at the moment of comparison. This is best attained by making both

solutions together in similar tubes immersed in the same water bath. Normal solutions of burnt sugar that have been recommended are not at all reliable; they become lighter by keeping, apparently by the aggregation and deposition of the minute carbonaceous particles upon which their color depends. The solution of the standard steel itself is liable to similar change, and must, therefore, be continually renewed. I have no hesitation in affirming that where this method has altogether failed, when applied to samples containing more than ½ per cent. of carbon, the failure was due to the operator and not to the method.

As regards the first objection, it is admitted at once, that the limits of error are wider in this than in other possible methods of carbon determination, for besides the personal equation above described its accuracy is obviously limited by the previous analysis that determined the carbon of the standard, and thus its own special errors may be either added to or subtracted from this, according to their direction.

But the practical merits of this, as of all things else, must be measured by fitness for intended purpose. By Eggertz method, skillfully conducted, the carbon combined with iron may be determined within five-hundredths or 1-20th per cent., which is sufficiently approximate for commercial purposes, and a demand for greater accuracy is mere pedantry.

The more accurate methods of carbon determination are so tedious that they are simply worthless for the purposes to which Eggertz is applied. To prove this I have only to state the fact that as many as forty blows of Bessemer steel were sometimes made at the Atlas Works in one day, and the carbon determinations of each of these were required within a few hours, or they would be useless. By Eggertz method my assistant was able to make all the forty determinations within five hours of obtaining the test-ingot drillings, and get his dinner in the meantime.

The second objection is quite sound. For quantities of less than two-tenths per cent. of carbon the Eggertz method is very uncertain. By using double quantity of steel and reading the result as half, it is sometimes possible to determine as low as one-tenth per cent.; in other cases this cannot be done, on account of a green tint, which occasionally appears in solutions of such slightly carburetted iron. Why this green tint should appear in some solutions and not in others I am unable to tell. All my hypotheses respecting manganese, &c., broke down when searchingly investigated, and therefore I leave the riddle for some one else to solve. When this green tint is absent, which is usually the case, we may, with care, get down to about 0.1 or 0.15 per cent. with tolerable reliability. In these more delicate and difficult determinations of shade it is well to use more than one pair of eyes, if possible, each observer independently noting his result and then comparing.

Another class of objections bear mainly upon the question of whether the knowledge obtainable by these carbon determinations is of any practical use in checking the proportions of spiegeleisen that should be used, and in classifying the ingots in order that the steel made by each blow should be devoted to its proper purpose. I pass over without further notice the incurable conservative stupidities of a certain class of workmen, foremen and managers, who blindly denounce every application of science as "theory," and who would extinguish every man who attempts an improvement by covering him with their bugbear epithet of "theorist;" but shall respectfully consider the fair objections of those intelligent practical men who have endeavored to use the information supplied by the chemist, but have met with difficulties and contradictions in so doing.

The source of one of these difficulties is pointed out in the above quotation. Silicon does undoubtedly add to the hardness of steel, and still more so to its brittleness. It is, therefore, possible to have two samples of Bessemer steel, one containing 0.4 per cent. of carbon and the other 0.5 per cent., and yet the first may be quite as hard or a little harder than the second, and much more brittle. This would be the case if the first contained a notable quantity of silicon, and the second only the ordinary trace. Exclusive reliance on the carbon would, therefore, in such a case be misleading. According to the carbon determinations the first should be used for rails and the

second for tires—according to actual hardness their uses should be reversed, as tires should be a little harder than the rails upon which they run.

I have only supposed a small discrepancy here because, practically, silicon can have but a small effect, seeing that the Bessemer process is especially effectual in oxydizing and removing silicon, which can only remain behind in practically appreciable quantity when the blow has been stopped too soon, or the spiegeleisen of bad quality.

There is, however, another and far more frequent and serious cause of discrepancy, which I discovered while at the Atlas Works. As a clear theoretical and practical understanding of this affords important aid to the successful working of the Bessemer process, I will state pretty fully the facts which led me to it.

The late Mr. George Brown was the manager of the Bessemer department, and to him a report of the carbon determinations of every blow was delivered daily. He had been engaged in steel making from boyhood, and was well versed in all the practical details of his business ; besides this, he had, without pretending to be a chemist, a sound acquaintance with what is known of the chemistry of steel, and broad philosophical convictions of the value of chemistry and its applications to steel-making, and these convictions were based on practical experience, which prevented him from falling into the errors of the over-learned, who would regulate everything by mere laboratory results. He accordingly applied the carbon determinations with their due and proper checks and limitations. Two test ingots were made from every blow—one for the laboratory drillings, the other for a *mechanical* test of hardness and brittleness by bending. These were marked with corresponding numbers and the chemical and mechanical results (which were obtained quite independently and apart) were compared. Usually they agreed in a remarkable and satisfactory manner, but whenever this was not the case I was informed of the discrepancy, and repeated the analysis, using this time drillings from the mechanical test-ingot to check possible error in numbering. When the discrepancy was confirmed, we "put our heads together" and tried to puzzle out the cause. In some cases underblowing and consequent presence of silicon afforded sufficient explanation ; at other times we traced it to silicon in the spiegeleisen. The influence of silicon, as described by von Ehrenwerth, was well understood by Mr. G. Brown. In other cases the silicon explanation would not fit the facts ; it threw no light upon the discrepancy and we were left in the dark respecting it.

I had already made several observations and experiments which led me to the conclusions—rather heretical at that time—that sulphur was far less mischievous to steel than phosphorus, and that the generally-received belief in the superior malignity of sulphur was only sound when applied to ordinary malleable iron. These conclusions are stated in a communication to the *Chemical News*, February 19th, 1869, in controversion of Dr. Miller, who stated that 0.298 per cent. of phosphorus in steel-iron "is obviously not such as to injure the quality," of Dr. Paul's assertion that 0.24 per cent. is quite a harmless quantity, and the general opinion then prevailing and expressed at a discussion in the Chemical Society to the effect that small quantities of phosphorus were harmless, or even, as some Continental chemists had stated, were beneficial to steel. Having satisfied myself that phosphorus is the worst enemy to steel, I made special analysis of the pigs and spiegeleisens used in the Bessemer department, and by following up this investigation, ultimately discovered that in every case where the phosphorus was above average the steel was harder than it should be according to its percentage of carbon, and that whenever the phosphorus was below average the steel was softer. I found that the hardening power of phosphorus was about three times as great as that of carbon, that one-tenth per cent. of phosphorus conferred about the same degree of hardness as three-tenths per cent of carbon. Not only was the hardness increased by the phosphorus, but the tenacity also. The breaking strain of the phosphorized steel as shown by tearing it asunder by the gradually-applied pull of an hydraulic testing apparatus, was remarkably high, much higher than steel containing

a similar amount of carbon and little or no phosphorus. These experiments showed that one, two or three-tenths per cent. of phosphorus increased the tenacity of iron as thus indicated—to a much greater extent than a corresponding amount of carbon, but they were not sufficiently extended to enable me to state in reliable figures how much greater.

Some readers, even at this date, will probably be puzzled by the foregoing statement, and suppose that I have contradicted myself; will say that if phosphorus thus gives hardness and tenacity, even to a greater extent than carbon it must be beneficial, and that it may be used instead of carbon. This was exactly the reasoning that led to the errors I endeavored to refute in the letter to the *Chemical News* above mentioned. The conclusions of Dr. Miller, Dr. Paul, and many others, were based on the tenacity displayed by the ordinary method of testing, by a gradually increasing steady pull, the breaking strain of iron, steel and other substances. If steel only required such hardness and such tenacity, then phosphorus *would* improve it. Further examination, however, shows that this phosphorus hardness is treacherous, it is accompanied with most deleterious brittleness. Glass is very hard, and will resist a tremendous longitudinal strain gradually applied, but is shattered by a blow or any other sudden vibratory shock. This is just the quality which I found to accompany the hardness conferred on iron by phosphorus. It produces a glassy rather than a steely iron, and, in small quantities, is less damaging to soft iron than to hard steel, especially if the soft iron contains sulphur; as phosphorus and carbon both tend to neutralize hot-shortness. Karsten goes so far as to state that up to 0.5 per cent. phosphorus is not damaging to iron, but rather improving. This, however, is an exaggeration.

The trials upon which I based the conclusion that phosphorus is especially deleterious to steel were those made by the drop test, and by hammering, or sudden bending. Steel containing phosphorus is more liable to crack, break, or crush when thus tested, and if a tool with an *acute edge*, such as a knife, a carpenter's chisel, &c., is made of such steel, its edge breaks and becomes notched if, in tempering, it is left hard enough even for cutting wood.

The most decisive experiments, however, were not quite so direct and simple as these, and were suggested by the fact that there is a practical limit to the amount of carbon that can be added to Bessemer steel. If this limit is slightly exceeded the steel, when hammered or rolled, cracks at the edges; if it is largely exceeded, an ingot placed as usual under the steam hammer crumbles like sandstone, even at a welding heat. In some samples this occurs at 0.75 per cent.; others will bear 0.90, 1.00, 1.25 per cent., or even more, of carbon without crushing. Why should this be the case with Bessemer steel and not with shear or pot-steel? was, of course, a very natural question. As the chief chemical difference between Bessemer steel and the best pot-steel is that in the former the sulphur and phosphorus of the pig remains unremoved, while in the latter these are taken out in puddling, or do not exist in the charcoal iron, I naturally replied that it must be one of these, and accordingly made analyses for sulphur and phosphorus in all the Bessemer pigs and speigeleisens that were used during a long period, and watched the results whenever a hard or highly-carburetted blow was made. It soon became evident that the phosphorus was the main cause of this rottenness, for the crushing point of the hard ingots and the cracking points of the ordinary daily bending, tests rose with the fall of the phosphorus and fell with its rise, *i. e.*, the greater the amount of phosphorus the less carbon the steel would bear. This was a really important discovery, so much so that Mr. G. Brown requested me to keep it as a trade secret, which I have done during his lifetime, but am now under no further obligation to do so.

A statement of all the details of these experiments would be rather tedious, but a general summary may be interesting.

The average crushing point of the Bessemer steel produced in the ordinary course of working was at about 0.90 per cent. carbon. The average composition of the Bessemer pigs and spiegeleisens used from July, 1868, to May, 1869, was as follows:

	Pigs.	Spiegel.
Combined carbon......	0.469	3.886
Graphitic carbon.......	2.719	0.474
Silicon...............	2.820	0.772
Phosphorus...........	0.082	0.056
Sulphur...............	0.139	0.148
Manganese	0.879	6.761
Iron (by difference)....	92.892	87.903
	100.000	100.000

The range of phosphorus in the pigs during this period (with the exception of one delivery, of which I shall speak presently), was from 0.02 to 0.15, and in the spiegeleisen from 0.03 to 0.12. As the pig-iron constitutes nine-tenths of the charge and is the most variable, this, of course, was chiefly watched. The quality of steel varied during this time and with these materials. There were two classes of variation—one that happened in a particular blow of inferior quality as an individual variation among a series: this class was generally referable to silicon and bad work, as above described; the other class of variations occurred in series, *i. e.*, the steel generally during a certain period was better or worse than average, and this period corresponded with the use of a delivery of pig of certain brand and quality. It was with these that I was now concerned, and I compared these variations of quality respectively with the variations of silicon, sulphur, manganese and phosphorus, and found that they fitted neither of the first three, but came as nearly in accord with the variations of phosphorus as the limits of error due to commercial analysis, mechanical testing, and possible variations of individual casts from the same blast-furnace, demanded.

The following five cases, showing composition of different deliveries and brands of pigs, will illustrate this:

	A	B	C	D	E
Combined carbon..........	0.62	0.20	0.50	0.37	1.25
Graphitic carbon..........	4.00	2.80	3.00	1.96	1.65
Silicon....................	1.40	2.33	2.00	4.08	2.15
Phosphorus................	0.02	0.02	0.03	0.15	0.24
Sulphur....................	0.06	0.10	0.10	0.23	0.21
Manganese	0.38	1.92	trace.	1.15	1.10
Iron by difference..........	93.54	92.63	94.37	92.06	93.40

The deliveries of pigs, A, B and C, produced the best steel ever made during the whole time I was at the Atlas Works, and the order of the quality, as estimated by George Brown, was as I have stated them. With "A," a remarkably fine sample of "Cleator" pig, very porous and abounding with "kish" (*i. e.*, spangles of uncombined graphite), and a selected spiegel, George Brown produced first class tool-steel, equal to pot-steel, by charging it with 1.25 to 1.50 per cent. of carbon, which it bore without loss of weldability (pardon the word, on plea of its convenience). The steel from B was not quite as good and from C slightly inferior to B, but both far above average.

D produced the worst steel that was allowed to pass, and the steel from E was so bad that it was condemned, and all the pigs returned to their vendor. This sample of steel was rotten, with only 0.50 per cent. of carbon.

The degree of superiority of A to B, with equal proportions of phosphorus, is explained by the abundance of carbon in the former. This is an important element in the excellence of Bessemer pigs. The lower proportion of sulphur is also advantageous, though not of the predominant importance that was formerly supposed. This is indicated in E, where the sulphur, although excessive, is less than in D. The usual statement that the Bessemer process does not remove any sulphur and phosphorus is not strictly correct. When the carbon is abundant, and the blow is consequently vigorous and prolonged, a small reduction of both of these (more of sulphur than of phosphorus) does occur.

George Brown assured me that, with good management, he could work with

silicon as a substitute for carbon, and that an abundance of silicon is advantageous both for increasing the energy of combustion and the amount of cinder, but that to work with such iron the highest degree of skill is demanded, the blow must be carried on to the last moment, and the converter turned over only just before its contents begin to solidfy. This is attended with some risk. I have had no opportunity of verifying this, myself, but have firm reliance in the accuracy and candor of Mr. Brown.

The practical applications of the above chemical generalisations may be made to contribute materially to the success of Bessemer work. I will first state their bearings upon the most common applications of Bessemer steel—rails and tires. Correct adjustment and uniformity of hardness is a primary desideratum ; the rails should be as nearly as possible alike, and the tires a little harder than the rails. It is obvious, from what I have stated, that the most skillful and scrupulous regulation of the carbon element will fail to afford the required uniformity unless the proportion of phosphorus in the raw material remains the same.

According to my estimate of the relative hardening powers of phosphorus and carbon viz., 3 to 1, steel made from pig D, containing 0.39 per cent. of carbon, will have about the same hardness as steel from pig A, containing 0.78 (the phosphorus of the spiegel is here neglected for simplicity of illustration), and therefore determinations of the phosphorus in pigs and spiegels are as necessary as determinations of the carbon in the steel. The importance of such determination becomes still more manifest when the other differences, besides mere hardness, are considered. Although, in the case just supposed, the D steel, with 0.39 per cent. carbon and 0.15 of phosphorus, may have the same hardness as the A steel, with 0.78 carbon and 0.02 phosphorus, it will by no means be of similar quality. It will be much more brittle, liable to fracture by vibratory strain, and less susceptible of that graduation of hardness obtainable by the tempering of true carbon steel.

Following up this difference, we arrive at a means of extending the Bessemer process to many other purposes than those to which it is commonly applied. All that is required for the manufacture of the best tool steel by the Bessemer process is to obtain pig-iron equal to A or B, and spiegeleisen of corresponding quality. It is not impossible to obtain this, but their is some difficulty in so doing, a difficulty which 20s. per ton added to ordinary prices of Bessemer pig would doubtless overcome. This tool-steel, of course, would demand the high percentage of carbon common to pot steel, which could easily be added, and with more certainty and uniformity than by the melting up of blistered steel.

But this is not all. There is a vast field open for the application of mild or semi-steel of reliable toughness and homogeneity. Bessemer steel-iron practically free from phosphorus and containing the lowest obtainable quantity of carbon, from 0.20 to 0.25 per cent., is invaluable for boiler-plates. Its tenacity is nearly double that of iron, and therefore it need be made of but little more than half the thickness of iron plates. These Bessemer plates being rolled directly from cast ingots are free from lamination, blisters and other irregularities of piled plates, and, by virtue of their carbon, can better resist the action of the fire. Girders and other elements of structure might be safely made of this semi-steel. We hear of many projects to build steel bridges. With this material the advantages of greater tenacity than iron, without the danger of brittleness, would be attainable.

Another application of such material may be mentioned. I had some sheets rolled from ingots containing 0.25 per cent. carbon and made from the same brand as A. These were sent to Messrs. Griffiths and Bowett, of Birmingham, who stamped them into vases and cylindrical cups of the form and proportions shown below. They were beaten and spun from a flat circular blank of the sheet metal. The object of the experiment was to ascertain whether a homogeneous cast metal could be used for the manufacture of tin-plate wares of superior quality. These are stamped first and tinned afterwards. When ordinary sheet iron, although made from the best charcoal-iron, is used, it often happens that

a portion of the surface is formed of cinder,—silicate of iron—that has not been completely squeezed out from the spongy mass of the puddled ball. This resists the tinning, and it has to be filed away, or the work, after much time and labor has been expended in shaping it, is quite spoiled and rejected as a "waster." The surface of the cast Bessemer semi-steel is perfect, and takes the tinning beautifully.

A multitude of other uses, such as steel pens, &c., might be named ; but these are sufficient to show that there is still an unoccupied field for manufacturing enterprise in the establishment of a Bessemer work where only the fine quality steel and steel-iron, such as was produced from pigs A, B and C, should be made, and sold at prices corresponding to their quality. In such a manufactory no low-priced heavy work should be attempted ; and if by mistake a few blows of ordinary Bessemer steel should be produced, the ingots should be sold to ordinary rail-makers, so that all the finished material bearing the brand of the works should be of uniform high-class quality. A reputation would thus be acquired, and large profits obtainable; but in order to secure such reliable quality the whole manufacture must be based on scientific principles, and no stint perpetrated in reference to the analytical examination of all the materials used, and the strict chemical investigation of every failure in respect to the quality of metal produced. Small or moderate-sized works, for high quality and high prices, rather than for large quantities, should be the aim. It might be advantageously affiliated with larger works, because there would, with every precaution, always be a liability to make inferior blows—by these I mean Bessemer steel which, though better than is now usually made, and useful for rails, &c., would not be good enough for the guaranteed quality that alone should bear the stamp of these works. There would thus be no absolute loss, even on the failures, and the high prices of the successful product would fairly reward the commercial enterprise and scientific skill demanded.

REPORT OF THE MASSACHUSETTS RAILROAD COMMISSIONERS.*

Abstracts from last Annual Report to Massachusetts Legislature.

The Railroad Commissioners respectfully submit their Seventh Annual Report.

The general and continued business depression incident to the financial crisis of September, 1873, has made itself felt much more perceptibly on the Massachusetts railroad system during the last, or second, year following the crisis, than it did during the first.

RAILROAD CONSTRUCTION

About fifty miles of railroad have been annually constructed in Massachusetts since the year 1835. In 1873-4, there were no less than 130 constructed ; in 1874-5, the amount decreased to 41 miles, and during the past year has still further decreased to 33.75 miles. Of this amount, 24.95 miles were of the standard, or 4 feet 8½ inches gauge, and the remaining 8.8 miles of the narrow, or 3 feet gauge. There are now 23 miles of road of the last description in the Commonwealth.

THE MILEAGE OF RAILROADS.

The total length of railroads reported to the Board for the last year was 2,459.202 miles of main line and branches, with 693.266 miles of siding, and 626.034 miles of double track,—the equivalent in all of 3,788,502 miles of single track. An increase of 77.409 miles over the preceding year, 36.668 of which are additional sidings. Of these totals there are within the limits of Massachusetts 1,816.748 miles of main track and branches, 504.907 miles of siding, and 440.114 of double track,—the equivalent

* Brief abstracts from "Public Document," No. 29.

of 2,761.769 miles of single track. This affords one mile of main track or branch road to 4.29 miles of territory, and to each 909 inhabitants. These are the largest averages to be found in America, though small in comparison with those reported in some European countries, where the population averages as high as 8,000 to each mile of railroad.

COST OF ROADS.

The average cost of the roads of the standard gauge is returned at $57,307.64 per mile, exclusive of equipment, which has amounted to an additional sum per mile of $7,774.47. The narrow-gauge roads are returned at $16,640.07 per mile, and $3,592.32 for equipment. The average cost of an equipped road, irrespective of gauge, is returned at $64,657.06 per mile, but varies from $98,606.19 for the Boston & Albany to $9,316.20 for the Martha's Vineyard.

EARNINGS.

The average sum earned on each mile of main line and branch road operated, was $13,250.84 ; if, however, the double tracks are computed as additional single track, the average amount earned per mile was $10,737.65. The amount varied from $30,003.41 per mile on the New York, New Haven & Hartford road, and $25,039.90 on the Boston & Albany, to $2,008.03 on the Springfield, Athol & North-Eastern.

COST OF OPERATION.

The cost of operation has amounted to $9,329.38 on each mile of road in use ; varying from $17,135.12 on the Boston & Albany to $1,400.48 on the Springfield, Athol & North Eastern. It has consumed 70 per cent. of the gross earnings, leaving a margin of 30 per cent. as profit on the year's business.

FREE PASSES.

The subject of free passes over railroads has recently attracted much public attention. With a view to ascertaining the extent to which the practice of granting these passes had been carried, a sèries of interrogatories were addressed to the several corporations.

The practice as regards passes varies greatly. Each corporation lays down a rule for itself, which seems in some cases to be quite stringent, and in others extremely lax. Many of the corporations seem to have practically kept no record at all, especially of trip passes, and to be unable to give any definite information on the subject. It may fairly be regarded as matter for surprise that at this late day a matter of so much importance as the free use of their roads should have apparently excited so little attention on the part of such a number of railroad officials.

The whole system should be broken up, though this probably cannot be done by law. The true rule would be for the conductor of a train to take up a ticket from every person on it, except the train hands. He should not be allowed to receive fares on the cars without in return giving a ticket, which he subsequently should take up as a train ticket. Employés, from the highest to the lowest, should, when on the business of the company, surrender employés' tickets, countersigned by themselves. When public officials travel on public duty, they should buy their tickets, like other passengers, and their traveling expenses should be regularly refunded to them. In this way, and in this way only, could a true and accurate record of travel be kept, and the abuses always incident to the pass system cut off.

COST OF RUNNING TRAINS.

The average cost of running a train one mile has been $1.169 on the passenger service, and $1.235 on the freight service ; varying from $0.432 for passenger service on the Springfield, Athol & North Eastern, to $1.908 for freight service on the New Haven & Northampton. The average rate on all trains has been $1.195 per mile, or 1.3 cents more than last year.

PROPORTION OF PAYING WEIGHT TO DEAD WEIGHT.

The average number of passengers to each train during the last year was 66, and the average number of tons of freight was 64. The passenger trains, including locomotives and baggage-cars, averaged 122½ tons of dead weight, and the freight trains 212½ tons. Consequently, the returns would seem to indicate that the railroad corporations of the State haul 1.778 tons of rolling-stock for each passenger they carry, and 3.292 tons for each ton of freight.

TRAIN MILEAGE.

The total mileage of passenger trains run during the year was 9,589,921, or a decrease of 297,080 miles from the previous year, being a decrease of 3 per cent. in service, corresponding to a decrease of 2 per cent. in earnings. As regards freight, 8,710,611 trains were run one mile, a decrease of 973,991 miles from two years previous, representing a corresponding decrease of $2,702,059, or 16 per cent., in the earnings from that source.

FARES AND FREIGHTS.

The average fare charged per mile on all the roads was 2.42 cents per mile, ranging from 5.6 mills per mile for season-ticket passengers for long distances, to ten cents per mile for single-ticket passengers for very short distances.

STEEL RAILS.

As regards the track, it appears that 1,040 miles out of 3,085, or 34 per cent., this year, as compared with 29 per cent. last, of the entire main lines of the corporations, are laid in steel,—an increase of 156 miles over the amount reported last year.

TRAIN BRAKES.

One of the most gratifying features in the returns this year, as last, is the rapid application of the train-brake to the passenger-rolling-stock. At the close of last year, it had been applied to 313 locomotives, and to 997 passenger-cars out of a total of 1,294. It is now applied to 353 locomotives, and to 1,227 passenger-cars out of 1,361. When it is remembered that at the time of the accident at Revere, just four years ago, the train-brake had been adopted by a single one only of the Massachusetts corporations, the advance made in this important respect will be appreciated.

It is, however, to be regretted that neither the Providence & Worcester nor the New London Northern roads have yet adopted this great safeguard. It is also an unfortunate fact that a difference in judgment as to the relative merits of different inventions has caused certain other corporations, operating roads forming parts of through lines, to adopt different kinds of brakes. Accordingly, when the through trains are made up at connecting points, the cars and the locomotive are so equipped that the brakes do not operate. The trains, accordingly, are reduced to a reliance on the old-fashioned hand-brake. There is reason to believe that at least one serious accident, which recently occurred beyond the limits of the State, was attributable to this cause.

STATIONS.

The number of stations returned is 1,151,—an increase of 75 over the number previously reported,—being a station to every 2.14 miles of road operated. In Massachusetts, the proportion is somewhat different, being one station to every 2.27 miles of road.

GRADE CROSSINGS.

The number of grade crossings is still rapidly increasing. There are 2,774 of these returned for the present year, as compared with 2,660 for the previous one,—an increase of 114 in a single year; 607 of these are protected by gates or flagmen. The number of casualties at these points is yearly becoming more noticeable. This fact has repeatedly been referred to in the reports of this Board. During the past year, as will be seen by reference to that portion of the present report relating to accidents, new and striking illustrations have been afforded of the dangers necessarily incident to the crossing of railroads by highways at grade.

SUMMARY.

In conclusion, it may be briefly stated that the average mile of single track road (the mile of double track being estimated at two miles of single track) of which returns are made to this Board, has cost $44,500, and that its equipment has cost an additional sum of $6,000, making a total of $50,500 for the mile of single track equipped road, which is represented by $36,500 of capital stock and $16,900 of debt. The gross yearly revenue from it is $10,563; of which $7,436, or 70 per cent., is consumed in the cost of operation, and $3,127, or 30 per cent., remains as profit. Fifty-one per cent. of the revenue is derived from the passenger business, and 44 per cent. from freights, and the balance from miscellaneous sources.

The record of accidents shows that, notwithstanding the strict economy which

all the railroad corporations have been obliged to practise in consequence of the generally depressed condition of their business, the personal safety of their passengers has not been neglected, and compares favorably with the statement for any preceding year. No passenger has been killed upon a Massachusetts railroad, and but six have been in any way injured, from causes over which they had no control, or to which they did not directly contribute by their own carelessness.

The whole number of passengers carried by rail during the year is reported as 42,035,846, and the average length of journey made was 15.07 miles. It follows, therefore, that the average journey by rail resulting in injury during the last year has been 105,580,036 miles, or that in traveling upon the railroads of this State the chances are that a person will travel more than one hundred and five million miles before sustaining any injury whatever from causes beyond his or her own control. Or, again, a person traveling 200 miles per day for 312 days in each year, may travel for 1,692 years before sustaining any injury to which he or she did not in any way contribute by their own carelessness.

The ordinary average of accidents of this nature in Massachusetts for the past five years has been in the immediate neighborhood of one passenger to each 1,400,000 carried. During the past railroad year it has been only one to each 7,000,000 carried. How creditable this record is to the care and skill with which the various roads have been operated, may be inferred by comparing the record with that of other countries where similar records are kept and reports published. During a period of ten years—between 1859-69—one passenger was killed or injured upon the railroads of France to each 674,000 persons carried; and in England the average for the last five years has been one passenger killed for every 8,388,980 carried, and one injured for every 318,000 carried, exclusive of season-ticket passengers.

The following statement shows the proportion of passengers killed and injured to passenger journeys for the four years ending 1873, and the year 1874, respectively, in Great Britain:

	No. of passengers killed from all causes beyond their own control.	No. of passengers injured from all causes beyond their own control.	No. of passenger journeys, exclusive of journeys by season-ticket holders.	Proportion killed from causes beyond their own control to number carried.	Proportion injured from causes beyond their own control to number carried.
1870 ... 1871 ... 1872 ... 1873 ...	142	4,698	1,589,912,975	1 in 11,196,570	1 in 338,423
1874 ...	86	1,613	480,000,000	1 in 5,581,400	1 in 297,582

The total number of casualties incident to the operation of the railroads of the State during the year, has been 242, as compared with 279 for the previous year. Of these, 36 were to passengers and 84 to employés, and the balance of 122 were to trespassers on tracks and to persons at crossings, etc. One hundred and nineteen resulted in death to persons, and 123 in personal injury only. More than 42 per cent. of the casualties (103) were occasioned by the unlawful practice of walking upon the railroad tracks.

Eighteen cases of injury, of which 13 were fatal, have occurred at highway crossings at grade (only half the number for the previous year), and five of these fatal cases occurred by a single accident on the Old Colony Railroad at Fall River, on the 27th of June. Eight of them occurred at crossings protected

by gates or flagmen, and 10 where there were neither gates or flagmen.

The Commissioners wish again, as they have repeatedly done before, to call attention to the very rapid increase in the number of highway and railroad grade crossings. On September 30, 1872, there were reported of these, in this State, 2,228; and on Sept. 30, 1875, there were 2,774: an increase of 546 in three years, or at the rate of a new grade crossing every two days. The facility with which these seem to be granted by the several boards of county commissioners on almost every application is most unfortunate. There is now a highway grade crossing to every mile and one-eighth of railroad in the Commonwealth. During the three years—1872–74—there were 31 persons killed and 38 persons injured at these crossings. During the last year the two worst accidents which occurred at them were at crossings provided, in one case with a gate, and in the other, with a flagman, showing that these are insufficient protections. As population increases so does the danger, and the only real remedy is never to permit the crossing of a railroad by a highway at grade when it can possibly be avoided. The law authorizing these nuisances should be revised, with a view to their future restriction.

RAILROAD ACCOUNTS AND RETURNS.

For several years past the Commissioners have in each of their annual reports, freely criticised the methods of book-keeping in use by the various railroad corporations of the State, and the character of the returns made from them. The railroad returns are, and must continue to be, essentially unreliable, if not even deceptive, until a radical reform in the methods of railroad book-keeping is effected. Upon this point the Commissioners have no new considerations of a general nature to offer. The cause of the difficulty is obvious. It dates from the very origin of the railroad system, when it was not at all appreciated what that system as a whole, or the several members of it individually, were destined to become. Railroads were then regarded as purely private enterprises managed by corporate bodies, in the doings and business affairs of which the holders of the company's stock alone were interested. They were supposed to be more analogous to turnpike corporations than to anything else, and enjoyed much the same exemption from public supervision, nominal returns only being made by them. Gradually, however, the public character of the functions they exercised became better understood, until, as long ago as the year 1846, only eleven years after the first three roads were opened in Massachusetts, the corporations were called upon by a general law for annual statements of their doings and condition, which since then have been published as part of the records of the State. In some other states of the Union, however, no such returns have ever been required, and nothing is known of the affairs of the railroad companies, except what their officials see fit to make public. Neither has provision ever been made in Massachusetts, or elsewhere, to secure any uniformity in the books and the methods of keeping them, which lie behind the returns.

A system might indeed be prescribed by law, and in some cases has been, but the carrying out of the system is left practically in the discretion of the several corporations. Until the year 1873, the Massachusetts returns seem to have been accepted as they were sent in, and published for what they were worth without scrutiny or comment. It is consequently almost needless to say that they were worth very little. For years their preparation was regarded by those on whom it devolved as a mere formal task, in which accuracy was of little importance. Accordingly, the earlier series of returns will not bear the slightest examination. Their errors and discrepancies are gross and apparent. It is, for instance, quite out of the question to ascertain from them even how many miles of railroad there were in Massachusetts at any given time; an item of information, perhaps, as important as any, and one in respect to which accuracy would seem not very difficult of attainment. In the year 1873 a wholly new system was adopted. The returns as they came in were very carefully scrutinized, and explanations of all apparent discrepancies required. In this way, when the figures were published, though this Board in no way held itself respon-

sible for their real accuracy, they were at least plausible.

They are, however, still often inaccurate, and at times even deceptive. Indeed, wherever those in charge of a corporation have any object to gain by a concealment of the true condition of its affairs, these returns afford an excellent opportunity, amounting to almost an invitation, for either the suppression of the true or the suggestion of the false. They do so in a very obvious way. They are collected by authority of law and compiled by public officials ;—they are prepared under oath and upon a uniform schedule of interrogatories, the answers to which are carefully tabulated. Under all these conditions the returns go out to the public with a species of endorsement of their truthfulness and accuracy on the part of the Commonwealth. They thus enjoy an authority which in no way belongs to them. In the popular mind it is naturally supposed that, as the results are uniform, the methods through which they are arrived at are likewise uniform, and it requires very considerable familiarity with railroad accounts to see that this is not the case. The returns of each road, on the contrary, are arrived at from a system of book-keeping peculiar to itself, through the application of arbitrary rules, which in different cases may or may not be the same, and which, in the case of corporations at all embarrassed financially, are almost certain to be exceptional. Under such a system it is in no way necessary to have recourse to fraud or misstatement in order to give to a company's affairs a desired aspect, whether favorable or otherwise. It can be done with perfect certainty, and yet the books be accurately kept and the results truthfully deduced from them. It is only necessary to apply to the real facts the arbitrary rules which each company lays down for its own guidance, and which do not appear on the face of the returns. The process is perfectly simple. The property of every railroad corporation consists of its road-bed and rolling-stock, and certain outside assets of uncertain value ; its income is derived from its business as a common carrier, and the greater part of it is necessarily expended in carrying that business on. Any balance over and above the amount thus expended constitutes the net earnings of the road. What the amount of this balance is, or may be made to seem to be, depends within very wide limits upon the arbitrary rules under which the accounts are kept. What in one case is charged to construction may in another case be charged to current expenses, or the reverse ;—the cost of renewals may be discontinued, and the property allowed to deteriorate ; or a certain amount of current indebtedness may be suffered to accumulate, and the unpaid vouchers be carried over from one year to another. Through any, or all of these processes, a road on the verge of ruin may be made to appear in a flourishing condition ; and, side by side with it, a road choked with remunerative business may be represented as daily going behind-hand. Yet all the while each return will be accurately drawn from the books, and, what is more, the officials of each company may very honestly consider that the returns made by them are the more correct in principle. Indeed, discretion and good judgment enter so largely into railroad accounting, that it has been in no way unusual for corporations to find themselves hopelessly bankrupt before those who managed their affairs were aware that they were in a position of danger.

The degree to which the balance representing net earnings may be apparently increased or diminished at will can be perfectly illustrated in a matter of now almost daily experience—the replacing of iron by steel rails. Of two corporations engaged in doing this, one is embarrassed and wishes to increase its apparent income ; the other is pursuing a conservative course and is improving the value of its property. Each must lay down some rule under which the unusual outlay for steel in place of iron shall be entered on its books. The embarrassed corporation so manipulates the account that the whole outlay is ultimately charged to construction ; while by the conservative corporation it is met at once out of its net earnings. When the cost of the steel is thus disposed of, the old iron still remains among the assets of the two corporations,—piled up along the track awaiting a purchaser. It must, therefore, appear in their returns as property on hand. One corporation charges it off its books as so much

material on hand required for use in yards, sidings, etc.; while the other will estimate it, not at its market value, but at its original cost, on the ground that it is still fit for use. Thus, by a simple and perhaps not dishonest manipulation of accounts, in a way which is not apparent on the face of the returns, a corporation which is doubling the value of its property may prove itself unable to pay a dividend; while another corporation on the highroad to insolvency may figure out a heavy surplus.

It is these returns, however, which now practically give to the stockholders as well as to the public all the insight they get into the condition of the railroad companies. The affairs of these corporations are so complicated and vast, and their constituency is so numerous and scattered, that the private investigations once possible are now out of the question. It is very difficult even for directors themselves to make them; impossible for any one else. Yet railroad securities are quoted and bought and sold in a way which was formerly peculiar to government bonds. The returns being, then, the only source from which information as to the value of these securities is to be had, they are, nevertheless of little value in the hands of one not accustomed to railroad accounts; while one familiar with the tests to be applied to them can make them produce thoroughly inconsistent results. Take, for instance, the test most commonly accepted,—that of the cost of running a train one mile,—and let it be appled comparatively among a number of not dissimilar roads. Into this cost enters all the expense of operating the road;—when it is returned at a large amount, it indicates that the company is putting its net earnings into its property; when it is very small, it indicates that the company is running down its property in order to make a favorable balance,—in other words, that it is living on its capital.

The accuracy of any result arrived at through the application of this test, necessarily depends, in the first place, on the correctness with which the mileage account is kept, and upon what in each case enters into it. That, again, is decided by arbitrary rules. Some corporations make the computation in one way, some in another. Take, for instance, the allowance for construction trains and switching-engines on the several Massachausetts roads. An examination of the replies to the special interrogatories, will show at a glance how widely these allowances vary. Among the roads leading out of Boston, for instance, one makes no account of the miles run by its switching-locomotives at all; while another enters them at 5 miles an hour, another at 6, and still a third at 7. The Fitchburg road, then, allows for them 50 miles apiece for each day, and the Boston & Providence 163. Presently another company renders a return in which they enter for the distance they actually run, the engine driver being supposed to keep an account. In the first place, therefore, there is no uniformity in the mileage account, upon which the value of the test depends. Accepting it, however, as the best attainable, it remains to apply it to the Massachusetts returns.

The true average cost of running a train one mile,—the standard cost for purposes of comparison,—may be arrived at with approximate correctness by taking the average of six of the Boston roads,—the New York & New England being excluded on the one side and the Boston & Providence on the other, as exceptional roads. The average cost of running a passenger train one mile is found to be $1.15, and that of running a freight train is $1.30; the average cost per train mile run, is $1.106. The test will be found applied in the accompanying table to the returns of fifteen railroad corporations for the last year. In the case of each corporation the total train mileage returned by it is multiplied by the standard cost of running a train one mile, and the result shows how much it may be assumed to have cost such company to operate its road during the last year. The next column contains the cost of such operation as actually made up from the company's books. The difference between the two may be taken to roughly indicate the policy of the several companies in regard to maintaining or depreciating their property during the year. It will be seen that the cost of running a train one mile varies 130 per cent.; that it ranges from 60 cents to $1.41; and the inference is irresistible, that, while some corporations

are using up their property year by year, others are accumulating it with equal rapidity. A small margin of difference is natural, and calls for no explanation. That it should cost the Old Colony 2 cents more or less per mile to run its trains than it does the Boston & Albany, is small matter for surprise. That it should, however, cost the Fitchburg 32 cents more per mile run to operate its road than it does the Boston & Maine; or the Eastern 42 cents less than the Boston & Providence; or the Boston, Clinton & Fitchburg 36 cents less than the Providence & Worcester,—these are discrepancies which can be accounted for only in one way. What that way is, may be inferred from the figures in the third, fourth and fifth columns of the following table. These columns show both what it ought to have cost these companies to operate their roads during the year, and what it is claimed that it actually did cost them:

	Cost per train mile as returned.	Standard cost per train mile.	Total cost of operation as per return of company.	Cost of operation at standard cost per train mile.	Excess or deficit of standard cost, as compared with cost reported in return.	Percentage of excess or deficit of standard cost, as compared with cost in return.
Boston & Providence	$1.417	$1.106	$1,134,021 89	$885,097 51	+$248,924 34	+28
New York, New Haven & Hartford....	1.360	1.106	2,727,397 96	2,216,492 57	+510,905 39	+23
Connecticut River...	1.273	1.106	419,679 65	364,484 51	+55,195 14	+15
Fitchburg	1.330	1.106	1,326,501 56	1,102,784 86	+223,716 70	+20
New York & New England.........	1.161	1.106	766,620 11	730,021 94	+36,598 17	+5
Eastern.............	.994	1.106	2,069,871 61	2,303,501 59	−233,629 98	−10
Boston, Clinton & Fitchburg	.832	1.106	718,314 75	954,575 33	−236,260 58	−25
Cheshire............	.918	1.106	581,444 84	700,404 36	−118,959 52	−17
Springfield, Athol & North-Eastern	.605	1.106	59,981 14	109,668 75	−49,687 61	−45
Boston & Maine.....	1.011	1.106	1,594,986 77	1,743,691 95	−148,705 18	−8
Providence & Worcester.............	1.190	1.106	653,220 96	604,672 32	+48,548 54	+8
Nashua, Acton & Boston...	.685	1.106	44,145 60	71,252 94	−27,107 34	−38
Worcester & Nashua.	1.077	1.106	336,079 21	345,020 02	−8,940 81	−3
Old Colony.........	1.119	1.106	1,553,744 40	1,534,553 99	+19,190 41	+1
Boston & Albany....	1.094	1.106	5,371,902 88	5,429,592 89	−57,690 01	−1

A similar difference of system among the several corporations is made apparent by a comparison of the cost at which their rolling-stock stands on their books. The variations are so wide as to be almost ludicrous. The explanation is again found in the fact that each company is a law unto itself. In one return, a number of new engines or cars made in the shops of the company during each year are charged as part of the expenses of operation, on the ground that they roughly represent the general deterioration of the rolling-stock. In another case, it will on examination be found that every addition to rolling-stock is charged to construction, and that old numbers are carried on the books long after that which they once represented has been condemned for deterioration. The present cost of a new, first-class 8-wheel locomotive weighing 30 tons is $8,000; that of a new, first-class passenger car, complete, is $4,600; while a box freight-car costs $700, and a flat or platform freight $5.75. On the books of the companies it will be noticed that locomotives vary from $2,507 to $12,-

565 ; passenger cars from $96 to $4,500 ; and freight-cars, box and flat (in the way the returns are made, the value of these cannot be separated), from $57 to $868.

Again, as respects passenger mileage. From this item in the returns are necessarily deduced, not only the statistical results in regard to accidents, but also the rates at which passengers are carried. In making it up, however, the several companies each have their own system. Among the Boston roads, six out of the eight altogether exclude from the aggregate passengers traveling on free passes, and many of them apparently do not even keep a record of the free passes issued. Two of the eight, however, are more particular ; and while this class of passengers appear in the returns of the Boston & Albany road as having traveled 1,642,513 miles, they appear in that of the Fitchburg for the larger amount of 1,814,248 miles.

The system now in use is, however, open to far greater objections than have yet been advanced. Its worst feature is the opportunity it presents for the practical falsification of accounts under great temptation to falsify. It renders not only possible, but usual, the most extraordinary and unwarrantable liberties with the principles of book-keeping. The construction account of a railroad corporation, for instance, is supposed to represent what its property cost,—the money actually put into it,—and what accordingly it is approximately worth. As a matter of fact, however, in not a few cases almost everything finds its way into it,—not only bad debts and discounts, but even interest and losses. Consequently, the more certain corporations lose and the heavier the discounts to which they are subjected as borrowers, the more their property appears to be worth.

There is but one remedy for such a condition of affairs ; that, however, is a very obvious one. It will be found in an increased publicity and more perfect uniformity. The last vestige of the old idea that the accounts of railroad corporations are matters of private concernment only, and as such can best be managed, in secret, must be gotten rid of. To bring about this result, a bill was prepared a year ago, and submitted by this Board to the joint legislative committee on railways. It was meant to be radical in its character, having been prepared in the full light of the many and notorious railroad scandals of the last ten years, and with the financial revelations which followed the crisis of 1873 still fresh in mind. It subjected the books of the railroad corporations to a constant and regular public supervision, with a view to securing accuracy and uniformity in the methods of keeping them. The results set forth in future returns were to be not only plausible, but they were actually to represent the exact condition of the affairs of each company, not only in themselves, but as compared with those of every other company. Where charges had to be apportioned under arbitrary rules, those rules were in all cases to be approximately the same. Where, under exceptional circumstances, deviations from those rules became necessary, attention was to be called to them as such.

The measure was considered by the committee, but no action was taken upon it. Finally, towards the close of the session, it was referred back to the Board with instructions to further consider the whole subject and to report to the legislature of the present year. (Resolves of 1875, chap. 67.) In accordance with these instructions, a new draft of a measure regulating the whole subject of railroad accounts and returns has been submitted. The bill is founded on the two fundamental principles already referred to,—uniformity and publicity, and is believed to sufficiently explain itself. It is proposed to no longer rely on answers to interrogatories derived from books privately kept by different methods and under numerous and dissimilar arbitrary rules ; but, instead of that, to cause the accounts of the future to be so kept that the returns when published shall be understood to mean what they say. On the other hand, it is not intended to establish any public auditorship over the railroad corporations, nor in any way to dictate to them as to how they shall spend their money. Nothing at all of this sort is contemplated. They will hereafter, as now, be at perfect liberty to dispose of their means in whatever way, wisely or unwisely, they see fit; only the disposition they make of it is to appear

distinctly and visibly in the returns, with a view to its being generally and correctly understood.

Should the measure now submitted, or any suitable substitute for it, become a law, the Commissioners are prepared to state exactly the course they propose to pursue. Under any effective measure, some one, presumably this Board, must be authorized to prescribe a system. To secure the most acceptable general result, the Commissioners would, at a suitable time, call together the representatives of the various roads, and request them to select from their own accountants a committee to prepare and report on a common system of book-keeping, with a body of rules for securing the utmost attainable uniformity in entries. This could better be accomplished by those representing the corporations themselves, than by any outside authority; and it is of comparatively small importance what system or what rules are fixed upon, provided they be uniform and intelligible. A general supervisor of railroad accounts would then have to be appointed. As the voluntary and friendly cooperation of the railroad corporations is of the utmost importance in this matter, and, indeed, essential to an early success, this appointment also should, if possible, be made acceptable to them. If they could agree in recommending a proper and competent man, he should be appointed. These preliminaries accomplished, it would only remain, on the first of next October, to set the machinery in motion. Thereafter, new questions must be settled as they present themselves. The aim of the Commissioners would, therefore, be to have this reform practically brought about by the voluntary action of the corporations; the law merely giving a necessary motive to it, and the Commissioners acting as the medium through which it may be rendered certain that some action will be had.

There would seem to be but two sources from which any oposition to a reform of this character can be anticipated. It may come from those whose past or future operations it would expose to a scrutiny they cannot bear, or from the vestiges of private railroad conservatism. Objections from neither source would seem to be entitled to any weight. Meanwhile, the whole body of legitimate investors in railroad securities are most directly interested in a movement so calculated to save them from a repetition of the frequent and scandalous disasters of the past. The public is not less directly interested in having that accurate information of the doings and conditions of its transportation agencies which is now impossible to procure. Finally, all honest and well-disposed railroad officials and directors are interested in the development of a system which will render fraud difficult, and and give to each company and its management such credit as is justly its due.

WHAT IS STEEL?*

By A. L. HOLLEY, C. E.

From "Engineering and Mining Journal."

The general usage of engineers, manufacturers and merchants is gradually, but surely, fixing the answer to this question. In every country rails, boiler plates and machinery bars, whether hard or soft, are almost universally called steel, when they are made from *cast ingots.* Other names for the softer steels, such as homogeneous metal," "Bessemer iron," "Martin iron" and the like, have failed to obtain general recognition.

The meaning of the term steel, before it was enlarged to cover newly developing varieties, has been traced, by a recent writer, down through Percy, Shakspeare and the Bible, in a most interesting manner, from an archæological point of view. Undoubtedly, it did characterize hardness and other qualities imparted by carbon. It is within the memory of most of us, that all steels were tool

* A paper read before the American Institute of Mining Engineers.

steels, and that the soft, structural varieties were introduced—varieties which harden but little, which bend cold, and which, in many physical properties are akin rather to wrought iron than to tool steel. But, since both the hard and the soft steels are made by the same processes, and have their great, distinguishing structural feature in common, viz.: homogeneity resulting from fluidity, it has come to pass, despite every other proposed nomenclature, that all the compounds of iron which have been cast in malleable masses, are called steel, the term wrought iron being still confined to malleable iron made from pasty masses, and hence laminated in structure.

No inconvenience has been found, so far, in distinguishing between the more or less carburized products, in general, by the terms "high steel," "low steel," "tool-steel," &c., and, in particular, by prefixing the percentage of carbon and other ingredients, to the term steel. Steels which contain distinguishing ingredients, other than carbon, are called "chrome-steel," "titanium-steel," and the like, just as variously compounded bronzes are called "phosphor-bronze," "aluminium-bronze," &c. Thus the combination of several words or symbols, and figures, may completely disclose the characters of the metal, in terms that are subject to no misunderstanding.

But inasmuch as several high metallurgical authorities and clever writers have of late proposed to disturb this natural and somewhat settled nomenclature, it seems important to consider the claims of the various classifications. I shall attempt, in this paper, to show that the existing classification is more scientific and more convenient than any other, and those others which have been most prominently brought into public notice are radically defective.

(1). The most common objection to the existing enlargement of the term "steel," so as to include the soft steels, is that it "pirates" a time-honored term, and applies it to a thing which is very different in many of its qualities. People who know nothing about steel, except as they use it in cutting instruments or read about it in classic authors, say that it is brittle, hard and resilient, and they are much shocked to hear that it may also be soft and ductile; just as any one who knows nothing about indiarubber, except in the form of springs, would be astonished to find that one change in manufacture turns it into waterproof clothing, and another, into hard, crystalline instruments and jewelry. The terms "hard rubber" and "soft rubber," as used in technical literature and commerce, have not given rise to any serious misunderstandings. People who do not know that the great bulk of the material made by steel processes, and having every ingredient and structural arrangement of the old steels, is, nevertheless, soft and ductile, and that it would be unsuitable for rails, plates, and the like, if it were not soft and ductile, are not to be considered authorities in this discussion, any more than a painter in coal tar, would for that reason be an authority on analine colors.

Where a material is gradually developed into new forms and qualities, there must be some general name to cover the various classes of metal; and whether it is better to enlarge the boundaries of the old one, or to arbitrarily make a new one, which new one must, from the nature of the case, merge into the old one, there being no natural dividing line, will be further considered throughout this paper. I venture to assert here that the charge, specially brought by the inventors of new definitions, against the existing use of the term "steel"—the charge of upsetting the recognized order of things—is wholly without foundation. Nobody *invented* the term "steel," as applied to the soft homogeneous products. There has been no natural or obvious place in the gradual gradation from hard to soft steels, to inject a new definition. As the possibilities of the crucible process were enlarged, the first soft product was hardly more than a variation from standard carburization; the early Bessemer and Martin steels, as produced in a successful commercial way, were hard, and, in fact, it is only quite recently that refractory materials have been adopted, by means of which the slowly receding standard of carbon in cheap steels, has reached a tenth of one per cent. The same general name has been thus necessarily preserved, for the products of the same process, but its boundaries have been enlarged to admit new varieties, and a gradual growth of sub-classifica-

tion. So that whatever the merits of any arbitrarily devised nomenclature may be, it must bear the demerit, whatever that is, of upsetting existing order and developments.

(2). A more common form of this objection is that a blacksmith would not recognize the soft metal as steel. "A blacksmith," it is said, "calls that steel which will harden and temper, and blacksmiths ought to know what steel is." There are various answers to this objection :

I. If familiarity with soft, coking coal teaches a blacksmith how to burn highly carburized anthracite in his smithy, then his knowledge of highly carburized tool-steel ought to teach him what soft steel is. Hard coal is none the less coal because it does not respond, like soft coal, to a blacksmith's coking process, nor is soft steel any the less steel, because it does not respond like tool-steel, to his hardening process. Anthracite coal was introduced long after bituminous coal was in general use, and the "pirating" of the time-honored name "coal," to describe this material which is so different in many of its qualities, has not led to any vast inconveniences. It may be said that the parallel is incomplete, because both hard and soft coals are really the same thing only changed in composition and structure by natural processes, and that they both respond to the practical test—the influences of heat and oxygen. So are hard and soft steel the same thing, only changed in composition and structure by natural laws ; and so do they both respond to the influences of heat and oxygen. Coals are, in fact, more diverse than steels in their carburization, structure and strength, and in their requirements of treatment. If old nomenclature is to be held as a final criterion, then the modern condensing steam-engine should be a "low-pressure engine." The fact is, on the contrary, that it is as often "high pressure" as any non-condensing engine.

The determination of previously unknown intermediate forms and functions is constantly enlarging the boundaries of all general classifications, and introducing sub-divisions ; hence the criterion of old classifications is inadequate and worthless.

II. If hardening in water is the determining characteristic of steel, who is to define "hardening?" As a matter of fact, all products of the crucible, Bessemer vessel, open-hearth furnace and feeding-furnace, containing about a quarter of a per cent. of carbon, will perceptibly harden in water, just in proportion to the carbon contained ; and every one of them, however little carbon it contains, will harden in some degree, so far as existing tests can determine. If the product will make a tool, it is steel," says the blacksmith. What kind of a tool ? Is an agricultural tool iron, and a cold chisel steel ; or does steel begin between cold chisels and razors, and if so, where? A water-hardened tool perfectly adapted to certain uses may be made of Bessemer steel containing half a per cent. of carbon. The same Bessemer ingot may make a good rail. If one-half the ingot is steel, why is the other half iron ? The line must be so defined that people will agree upon it. Does it lie between thirty hundredths and thirty-one hundredths of carbon, or between ninety-nine hundredths and one per cent ?

Obviously, no two men can agree on the amount of any hardening element which may constitute steel. And if they could agree, it would only be after a quantitative analysis had been made in all close cases.

III. A recent writer makes a number of ingenious objections to the use of the word "steel" for all compounds of iron which are cast into malleable masses.

I. The term "steel" is said to be so vague that some words must be added to it to indicate the very dissimilar classes of steel, and the necessity for this explanation is deemed objectionable.

This objection is best answered by its author, who says that it is desirable to discriminate between the different classes of iron, and proposes the following brief and convenient nomenclature :—"Cast steel, welded steel, homogeneous wrought iron, homogeneous iron, welded wrought iron, puddled steel, puddled iron, blistered steel, Bessemer steel, Bessemer wrought iron, open-hearth wrought iron, Uchatius steel, Uchatius wrought iron, crucible steel, crucible homogeneous iron, &c." This classification, he says, shows whether the metal

"has the properties given by carbon." Now, every one of these metals has properties given by carbon. The percentage of carbon must be mentioned anyhow, so why not briefly say twenty-carbon steel or forty-carbon steel, and so denote both its carbon value and its homogeneity ?

The objection, in its common form, is that the one word "steel" does not, without further explanation, define the various classes of metal referred to. Neither do the words "oil" "coal," "rock," "brass," nor great numbers of general names express the sub-classes referred to ; nor can any word or any simple sentence define them all. The objection holds equally against all possible general classifications, and the only way to avoid it here is not to have any general classification in the iron business.

II. The writer referred to objects to calling the soft homogeneous compounds "steel" because it is sometimes difficult to tell whether they were made from cast or from pasty masses. It is true that a well-worked puddled iron, rather high in carbon, and a low steel with about the same carbon, cannot be distinguished very easily by means of ordinary observation and simple tests.

I will, in answer to this objection, quote the same writer, who admits the impossibility of any perfectly adequate definition by saying that "classifications are based on important differences between the classes they separate, and not on the facility of distinguishing those classes sharply." Now, there are important structural differences between puddled irons and cast steels which look alike—differences which will make themselves known after sufficient stress and wear ; but is the difference between two steels varying only by a hundredth of a per cent. of carbon, one of these "important differences," upon which an adequate classification may be based ?

The real answer to the objection, however, is this :—Admitting, for the sake of argument, that a considerable range of wrought irons and low steels cannot be distinguished by the observation of their fracture, nor by bending, nor by the usual quick mechanical tests—people do not largely purchase iron and steel by sampling individual pieces, as they would cigars ; they purchase by specification of *manufacture ;* for instance, the Pennsylvania R.R. Co. specifies 0.35 carbon steel for its rails, meaningly "steel," that it shall be homogeneous or cast ; and from 0.30 to 0.40 carbon is recognized by makers and users generally as the proper percentage for rails. I note this fact here to correct the writer whose objection I am quoting. In trying to explain away the fact that such rails are recognized as steel, he says : "Railway managers do not care much about the degree of carburization of rails said to be steel, provided they are absolutely weldless."

The practical usefulness of a name does not, therefore, lie so much in its discrimination between metals after they are made, as in specifying the method and quality of their manufacture. Rails, plates, bars, and iron and steel generally are ordered on the understanding that they shall be fabricated by processes and of ingredients which are known to have yielded certain endurances to long continued stress and wear. If purchasers themselves do not specify the ingredient and processes they want, they specify a name and grade of metal, such as "0.60 carbon Martin steel," which refers the manufacturer to such ingredients and process ; so that the name completely meets the requirements of the case.

Supposing even that it should be, not difficult, but impossible to distinguish between certain grades of steel and wrought iron by the most searching mechanical and chemical analyses—it can probably be determined in all cases from synthesis. Lawsuits arise as to the composition of material substances about which we have no synthetical record, such as a late suit about a certain paving stone, based on the question as to whether it was trap-rock, or a sandstone altered by the trap-rock that flowed over it. But there are almost always sufficient records of manufacture to determine whether a metal has been cast or welded. This, however, is an extreme case ; perhaps it is one that could never occur. Destructive tests, can, I believe, determine in every case whether a metal was cast or welded. In the great majority of cases the most simple tests can distinguish iron from steel, as at present defined, so that practically the existing classification is entirely adequate.

III. The writer we are quoting misinterprets the current definition of steel, as calling for a product which is *better* than wrought iron ; and then he attacks the definition by saying : "Who would call cold-short Bessemer ingots, on the whole, superior to the best Swedish iron?" Now as cold-short ingots are altogether *nil* until they have been reconstructed, we must admit that "a living dog is better than a dead lion." The bearings of his observation do not lie in its application.

IV. Another objection from the same source, that the current definition excludes certain classes of iron heretofore called steel, such as "blistered steel," "puddled steel," &c.—is at first sight a valid one. But should not the same objection also be valid against the old and limited meaning of the term "steel"? Does the mere fact that "puddled steel," so called, is carburized more than the usual products of the puddling furnace, although less than tool steels—does this mere fact of a little more carburization really define steel, according to the old restrictions of the term, despite the fact that the product, so called, has a totally different structure which renders it unfit for tools and for most other things that steel is used for? If, then, the term "puddled steel" should be excluded under the old classification, surely the classification now current must not be held responsible for its exclusion.

V. Again, classing homogeneous irons high in carbon and those low in carbon, under the same name—"steel"—is objected to, because the range of properties and uses due to variations in carbon, are much greater than those due to variations in homogeneity. Hence the classification, it is said, should be based on carbon and not on homogeneity. Every malleable iron, whatever it is called, contains carbon in some proportions, from a trace to the highest attainable solution, and since these combinations and the properties they impart, form a regular series of variations, running into each other, there can be no general carbon classification, except by drawing an arbitrary line at some carbon percentage. Now (1st) as the irons for some distance on both sides of this line cannot be thus distinguished, except by minute analysis in every instance ; (2d) since synthesis, which is the practical matter, cannot be based on a carbon specification alone, because it would omit the vital feature of homogeneity, upon which depend, for instance, the advantages of steel rails over iron rails ; and (3d) since a classification based on homogeneity furnishes means for distinguishing between products, while it also affords, with the addition of the carbon percentage, a perfect basis for synthesis—for these reasons I fail to see why a carbon basis, which must be arbitrary and revolutionary, could be useful or desirable. (4th) No less prominent an authority than Whitworth has proposed to divide wrought iron from steel at the point of twenty-eight tons tensile strength. This classification is open to all the objections we have urged against the equally unnatural and arbitrary carbon classification. How would Mr. Whitworth like to order gun-steel by this definition? Any steel-maker can produce a metal so full of phosphorus and silicon that it will fly into pieces under a sudden blow, and yet it will stand over twenty-eight tons statical pull. A steel made with very small proportions of carbon and manganese, to the almost entire exclusion of phosphorus and silicon, would safely stand the severest blows, and stretch perhaps thirty per cent. before breaking, but still it might barely reach twenty-eight tons tensile strength. A puddled iron totally unfit for guns, plates and rails, might stand twenty-eight tons statical tension, while the most pure and costly product of the crucible might fail under it. The former, according to this classification, would be steel—the latter wrought iron. (5th) It has been stated that what is known as "malleable iron" will confuse the existing classification. Seeing that iron is remanufactured into malleable iron by a subsequent process, and not cast while in a fluid state into a malleable mass, as our specification demands, this objection is absurd. Without answering the more trivial objections, let us consider what we are to do if we give up the existing classification.

I. The old and restricted term "steel" indicated certain properties, such as resilience, hardness, &c., in an indefinite degree, which were imparted by that indefinite amount of carbon which gave hardening and tempering qualities. Now

what shall we call the structural steels? We cannot call them wrought iron because they have all the enumerated features, even hardening and tempering in a gradually lessening degree, as carbon is diminished; and the features are not characteristic of wrought iron. Besides, wrought iron totally differs in feature of homogeneity, and is rapidly growing out of use to make room for the homogeneous compound.

II. We may call these compounds "homogeneous iron," but we must then add the percentage of carbon, and designate them as "ten-carbon homogeneous iron," up to, say "fifty-carbon homogeneous iron," for there is a vast range of grades and uses between these carburizations. Now, is it not easier to say "ten-carbon steel" up to "one hundred and fifty carbon steel," thus including all the varieties of ingot metal? And is the general public likely to agree that "homogeneous iron" means metals made from ingots, up to a certain arbitrary point of carbon, which nobody can determine without analysis, when beyond this point, ingot metal, made exactly in the same way and by the same furnaces and processes is "steel"? The inconvenience of such a nomenclature is illustrated by certain streets in London, which are called by one name up to a certain number, and by another name the rest of the way—a very inadequate illustration, for one can sometimes find a label on a street, without making a quantitative analysis.

6. As the author referred to, whose objections I have endeavored to answer, has offered, not dogmatically, but for discussion, a new definition of steel, and has advocated its claims with much learning and ingenuity, I think we ought to examine it in some detail. He defines steel as "a compound or alloy of iron whose nodulus of resilience can be rendered, by proper mechanical treatment, as great as that of a compound of 99.70 per cent. of iron with 0.30 of carbon can be by tempering." This is substantially an arbitrary division at the carbon point, 30 per cent., of all malleable iron compounds, whether made by wrought iron processes or by steel processes. The chief reasons appear to be (1) that this division somewhat corresponds to the distinction made between wrought iron and steel at a time when there were no soft steels; (2) that the carbon point, 0.30 per cent., is a "somewhat critical point in the curve representing the degrees to which differently carbonized varieties of iron possess the properties which are most affected by carbon"; (3) that resilience being the chief attribute of steel, it should for this reason form a basis of classification.

I. It is difficult to understand why scientific men should be willing to sacrifice a natural classification, which has grown out of the necessities of the case, for one that is unnatural and arbitrary, on the ground that it embraces species which are unlike the earlier species, although of the same genus. It is hardly necessary to repeat what has been said again and again in the foregoing pages on this subject.

II. If the 0.30 carbon point is a critical one, which I have not practically noticed, and which, for the purposes of this paper, need not be discussed, it is stated to be a point in a *curve*, which must be arbitrarily placed, and not the point of an angle, which might distinguish homogeneous from welded masses.

III. As to resilience being the most important quality of steels, and for that reason the proper basis of classification, it is unnecessary to discuss this claim for resilience here. The question is whether the importance of a quality can make existence of that quality a definite basis of classification when it exists in both classes, gradually increasing in one and decreasing in the other, and being practically the same near the dividing line.

To sum up once more, the answer to this and to all the cases of arbitrary classification: Exact definitions must be based on differences which always exist in every form and phase of the materials defined, and not on differences which, however great they may be in certain forms and phases of the materials, run together at one point, and there cease to be differences. If we divide steel from wrought iron by an arbitrary line of percentage of any ingredient or of modification due to any ingredient, there must be some point at which the difference between steel and wrought iron is infinitely small. If, however, we define steel as a compound made homogeneous

by fusion, while wrought iron, although the same in composition, is heterogeneous from welding, there is always and at every grade of the respective materials, a large and radical difference. Casting fluid steel and welding pasty iron are always distinct in their characters and results; they do not at any point shade into each other. The latter classification is, therefore, exact and complete.

IV. A very serious objection to the proposed division is that it occurs at a point about midway in the range of structural steels. It would be less inconvenient, though not less unscientific, if it divided the general class of structural steels from the more ordinary grades of tool steels. Of a pair of locomotive tires, both made by the same process, out of the same materials, and containing as nearly as practicable 0.30 carbon, one might be steel and the other wrought iron; or a pair of locomotive tires might both be steel, the one having been welded up from scrap and the other drawn from a cast ingot; or, one end of the same ingot might be steel and the other end wrought iron, the first having been hardened, and the other annealed. The convenience of such a nomenclature is not obvious at first sight.

The author of the proposed definition we are criticising has so vividly portrayed the disastrous confusion which would arise from changing a settled nomenclature that I can hardly do better than quote him in this connection. He says:—"It is a complete change in the meaning of a word that is in every man's mouth—a change in which the interests of the whole civilized world are affected, and in contemplating which the convenience of all mankind is to be considered. The natural conservatism of language would prolong this painful period of change to a most unpleasant length. Moreover the confusion would not end till the change had been well established in the other languages of the civilized world. In meeting the word 'steel' in specifications, contracts, and, indeed, all literature, whether technical or not, whether English or foreign, it would be necessary to determine whether it had been written before or after the change had been effected."

In conclusion, it seems hardly necessary to *again* sum up what has been chiefly a reiteration in different forms of answers to criticisms on the present enlarged use of the term "steel," and of the one great objection to the nomenclatures, that they are fatally indefinite. The names of new materials and processes, like the laws of trade, are not fixed by the arbitrary edicts of philosophers, but they are gradually developed to meet the general convenience.

A BALLOON WITH POWER.

From "The Builder."

On the 2d of February, 1872, M. Dupuy de Lome made a satisfactory ascent from Paris in a balloon constructed by him, and provided with a screw for propelling and steering it. The screw was then worked by manual power, and the rate of progress was comparatively slow. M. Dupuy de Lome expressed at that time his belief that its speed might be increased if, instead of the weight of the eight men working the screw, an eight-horse-power engine were taken into the car. The only drawback to such a plan was the liability of the engine to set the balloon on fire. According to a communication in the *Jahresbericht des Physikalischen Vereins zu Frankfurt*, 1875, an important step in advance in this direction has now been taken. Herr Hanlein, civil engineer, of Mayence, has invented and constructed a balloon driven by a gas-engine. He has proved by his invention that, by increasing the size of the balloon and by other improvements, an increased rate of speed may be attained.

If we suppose a screw-steamer cut off just above the water-line, so that it moves only in one element, viz., water, that it finds its resistance in water, that the point of attack for its driving apparatus lies in it, and that its helm like-

wise acts there, this case is perfectly analogous to the movement of a balloon which may be driven and guided in the air. Of course, the driving apparatus of a balloon has to overcome a very much smaller amount of resistance than a vessel moving in water; but, in the same proportion, the resistance which a body propelled in the air meets with is less than when it is moved in water.

The impetus in boundless water or boundless air is calculated according to the formula:

$$P = \Sigma \cdot \frac{v^2}{2g} \cdot F \cdot \gamma,$$

in which Σ is a co-efficient depending upon the form of the body; v, the speed of the body; F, its greatest cross-section; γ, the density of the medium; g, the weight of the earth.

It will be seen from this formula that the impetus for congruent bodies, with equal velocity, depends solely upon the density of the medium in which they are immersed. The density of air being $\frac{1}{800}$ of that of water, the resistance a vessel propelled in air meets with, compared with that of another vessel propelled in water, is in the same proportion. In like manner, the pressure of the screw against air amounting to only $\frac{1}{800}$ of its pressure against water, and the resistance of the propelled body and the pressure of the screw being less, at the same rate, in air than in water, the final result, velocity, is the same.

Without (for the sake of simplicity of theoretical examination) taking account here of the coefficients modifying those relations, it may be said that the force necessary for moving a body in the air is only $\frac{1}{800}$ of the force which must be applied to move a similar body with the same velocity in water.

A like relation exists also between the bearing capacity of the balloon and that of the ship. A ship, for instance, the volume of which under water amounts to 1,000 cubic metres, has a bearing capacity of 1,000,000 kilometres, while a balloon of the same dimensions, filled with hydrogen, is capable of carrying only 1,250 kilometres, or $\frac{1}{800}$ of the capacity of a ship. The balloon motor absorbs in weight about the same percentage of the balloon's carrying capacity as the ship's engine does of the carrying power of the ship. Supposing a screw steamer and a balloon to have the same dimensions, the latter will require only $\frac{1}{800}$ of the power of the ship's engine in order to attain a speed equal to that of the ship. In this case, it is supposed that the effect of the air screw is equal to that of a water-screw. But as it is not possible to make the sides of a balloon as smooth as the sides of a ship, the meshes of the netting causing small bulgings, though only on the upper surface of the balloon, and thus increasing resistance to its movement, its speed will be proportionately less.

Hitherto there has been a want of motor in the use of which the weight of the necessary mechanism stands in the same proportion to the carrying power of a balloon as, for instance, the weight of the boiler with contents and fuel to the carrying capacity of a steamship. Hanlein, in the first instance, obtained a patent (in 1865) for the combination of an air-screw and gas-engine for the locomotion of balloons, and included in this patent the application of a smaller balloon, filled with air, which, in the interior of the balloon proper, served the purpose of preserving the form as well as the volume of the latter. The smaller balloon acts in two ways. As soon as the balloon reaches the higher strata of the atmosphere, the gas with which it is filled expands, expelling a corresponding quantity of air from the inner, smaller balloon. In the case of the consumption of gas for the supply of the gas-engine, the inner balloon expands by taking in atmospheric air by the action of an air-pump.

In 1870, Hanlein constructed his first model, with a length of balloon 38.94 ft. He was enabled to carry out his plans by the generosity of a few rich Frankfurters, who provided the necessary funds in the interest of science. The first experiments with the model were made in the following year at Mainz, and Hanlein's principle was found in practice not only perfectly sound, but it led to the conclusion that, with a balloon constructed on a large scale, it would be possible, by means of a gas engine of corresponding size, to attain a speed which would permit of overcoming, throughout the year, with few exceptions, the velocity of the wind. In 1872, Hanlein constructed a

second, larger, balloon, capable of carrying, besides the necessaay apparatus and outfit two persons.

This balloon, of the form of a rotatory body, with a longitudinal section like the water-line of a ship, has a length of 166.32 ft., and a diameter of 30.36 ft. The covering of the balloon consists of closely-woven silk, having a thick layer of caoutchouic inside and a thinner one outside. The ten strips forming the balloon are jointed perfectly gas-proof by means of strips 1.18 in. wide of a similar nature. The balloon is surrounded by a net, the meshes of which are 3.94 ft. square. Each mesh is connected from the terminal meshes of the sides with a cord 6.6 ft. long. Each twelve of such cords are united in a loop, and from each of these loops a stronger rope leads to the car. The back cords do not lead direct to the car, but unite at a strong cross-beam 15.84 ft. long, forming the space required for the play of the screw. All the ropes leading from the car to the net meet the balloon tangentially. To prevent the horizontal strain exerted by the front and back ropes upon the car, they are, running under the car, connected by other ropes diagonally with each other. Thus the whole weight of the car rests in a perfect network of ropes, the car being further suspended at a number of other points, thus reducing the strain upon the apparatus to a minimum. Between car and balloon, 18.15 ft. under the balloon axis, is a frame, of such a form that the ropes connecting the car with the balloon cross the frame tangentially, and thus may be fastened on to it. This frame carries the side-posts and stays supporting the steering-apparatus and cross-pieces for the transmission of the steering, and serves for a resting-point for four stays connected at their lower ends with the car. Two buffers, fastened underneath the car, protect the screw in case of the balloon touching the ground. All the supports, stays, &c., are made of very light soft wood, and are of the shape of fish-bellied bearers. They consist of four rods, which are held together by cross-pieces (crosses or rings) at intervals of 11.8 in.

Besides the usual inlet and escape valves for gas, the balloon is provided with two safety-valves, which open at a pressure sufficient to keep the balloon perfectly tight and extended. In the interior of the balloon is the smaller one, already mentioned, filled with air.

The gas-engine consists of two pairs of horizontal cylinders, acting upon a common crank-axle, by means of four cranks. Each two of them are opposite to each other, and form with the two others right angles. By this arrangement the pitching which would otherwise be caused by the forward and backward movements of the pistons is neutralized to a great extent. The screw is secured to the extremity of the crank-axle. The explosions are effected by the electrical spark of an induction apparatus. The engine is a Lenoir engine, its parts being made hollow, to reduce the weight of the whole. It makes ninety revolutions per minute. The diameter of the cylinders is 6.3 in.; that of the screw, 15 ft.; the pitch of the latter, 20 ft. The screw has four blades, and is in form like Griffith's screw. The sides and ends of the cylinders are surrounded by cold water, to prevent them from being too highly heated. As but little water can, however, be carried, it is conducted from the cylinders in so-called coolers along the car. In these coolers the heated water comes into contact with the air passing through them. An aliquot part of it evaporates as the rising power of the balloon diminishes in consequence of the consumption of gas. The cooled water is brought back to the cylinders by two pumps, driven by the engine. The cooling surface is large enough to ensure an ample supply of cooling water, about 150 lb. being a sufficient store. The engine takes the gas it consumes direct from the larger balloon. In proportion as the consumption of gas goes on, the inner, smaller balloon must be extended by air.

The cubic spaces of the balloon, as measured by a meter, is 25,922 cubic feet. From this, the carrying power may be calculated as follows:

	Lb.
If the balloon is filled with gas of 0.50 sp. gr., it is	3,128
If the balloon is filled with gas of 0.45 sp. gr., it is	3,440
If the balloon is filled with gas of 0.40 sp. gr., it is	3,756
If the balloon is filled with hydrogen gas it is	5,828.

The weights to be carried are:

	Lb.
Gas engine	466
Screw	158
Frames, cross-bearers, steering apparatus, buffers, &c.	498
Cooling apparatus	220
Car	248
Covering of balloon	700
Net, with ropes	292
Battery, with inductor	80
Water	150
	2,812

Supposing the specific gravity of the gas to be 0.45, there would remain 628 lb. for two persons and their equipment.

At the experiments carried on at Brunn, the gas used was so heavy that the car had to be considerably lightened before it would carry two persons. On that account a regular ascent could not be made, and the balloon was secured by ropes, and propelled by the engine a distance of nearly 2,000 ft. It was found that the engine acted perfectly satisfactory; the balloon moved with the wind, and against the wind, was propelled in a circle by means of the steering apparatus, and was perfectly manageable. In being propelled against the wind, a good rate of speed was attained. The engine consumed per hour from 70 to 75 cubic feet of gas, and from 20 to 25 lb. of cooling water.

It will thus be seen that, if all the parts are made still lighter, and lighter gas,—for instance, hydrogen gas,—is used, and the balloon is made of larger dimensions, a high rate of speed seems possible.

ON THE EFFICIENCY OF BELTS OR STRAPS AS COMMUNICATORS OF WORK.

By Professor OSBORNE REYNOLDS.

From "The Engineer."

It has often been remarked that it seems to be impossible so to construct belts that they shall drive without slipping. I am not aware that any reason has ever been given for this; but, on the other hand, most writers seem to have assumed that if the belt is made sufficiently tight, so that the tension on the slack side is from one one-half to one-quarter that on the tight side, according as the strap is in contact with one-half or the whole of the pulleys, it will not slip. The object of this communication is to show that not only is a reason to be given for this residual slipping, but that it follows a definite law, depending on the elasticity of the strap, and independent of its tightness over and above what is necessary to prevent it slipping bodily round the wheel.

When a pulley, A, is connected with another pulley, B, by a belt, so that A drives B, it is usual to assume that the surfaces of the two pulleys move with the same velocity, namely, the velocity of the strap; and that the work communicated from A to B equals this velocity multiplied by the difference in the tension on two sides of the belt. This law would doubtless be true if the strap were inelastic, and did not stretch at all under the tension to which it is subjected; but as all straps are more or less elastic, it can be shown that this law does not hold rigorously, although with such an inelastic material as leather it is not far from the truth.

Owing to its elasticity, the tight side of the belt will be more stretched than the slack or slacker side, and will, in consequence, have to move faster. This is easily seen when we consider that each point on the strap completes its entire circuit in the same time, so that if at any instant a number of marks were made on the strap at different points, these marks would all return to the same points in precisely the same time; for the velocity at each point would be equal to the length of strap which passes that point, and on the tight side this would be the stretched length, whereas on the other side it would be the unstretched length, and hence the two sides of the strap would move with different velocities, according to the de-

gree in which the strap is more stretched on the one side than on the other.

Now the stretching of a strap will be proportional to tension, although the degree will depend on its side and the material of which the strap is composed. Let $\gamma\ \pi$ represent the increase in length per foot in a certain strap, caused by a tension of π lb. Then, if π_1 and π_2 represent the tensions on the two sides of the belt respectively, the stretching on these two sides will be respectively proportioned to $\gamma\ \pi_1$ and $\gamma\ \pi_2$, and the difference will be proportional to $\gamma\ (\pi_1 - \pi_2)$. Therefore the velocities of the two sides will be in the ratio $=\dfrac{1+\gamma\ (\pi_1 - \pi_2)}{1}$.

Again, it is easy to see that the velocity of the tight side of the strap must be equal to that of the surface of the pulley A which drives it; whereas the velocity of the pulley B, which is driven by the strap, will be the same as that of the slack side of the strap; and hence the velocities of the two pulleys differ in the ratio $\dfrac{1+\gamma\ (\pi_1 - \pi_2)}{1}$. And since the turning effort of the strap on either pulley is the same, namely, $\pi_1 - \pi^2$, the difference of its tensions, the work done by A, which equals its velocity into this effort, will be greater than that taken up by B in the ratio $\dfrac{1+\gamma\ (\pi_1 - \pi_2)}{1}$. This excess of work will have been spent in the slipping, or more properly the creeping, of the strap round the pulleys. The manner in which this creeping takes place is easily seen, as follows:—The strap comes on to A tight and stretched, and leaves it unstretched. It has therefore contracted while on the pulley. This contraction takes place gradually from the point at which it comes on to that at which it leaves, and the result is that the strap is continually slipping over the pulley to the point at which it first comes on. In the same way with B; the strap comes on unstretched and leaves it stretched, and has expanded while on the wheel, which expansion takes place gradually from the point at which the strap comes on until it leaves.

The proportion which the slipping bears to the whole distance traveled by the strap $= \gamma\ (\pi_1 - \pi_2)$, which, as previously shown, is the proportion which the work lost bears to the whole work done by A. From this it appears that the slipping and work lost are proportional to γ, *i.e.*, to the increase which a tension of 1 lb. would cause in 1 ft. length of the strap; and hence, the more inelastic the material is, the better it is suited for belts.

The actual amount of this slipping may be calculated when we know the elasticity of the belts. With leather it is very small. One belt, which had been in use about two years, and was 1.25 in. wide and $\frac{3}{16}$ in. thick—the usual thickness—increased in length by sixteen-thousandths under a tension of 100 lb. From this example it appears that, for a leather belt of breadth b in.

$$\gamma = \frac{20}{100{,}000}\ \frac{1}{b}$$

Hence the ratio of slipping $= .0002\ \dfrac{1}{b}$ $(\pi_1 - \pi^2)$; and in practice $\pi_1 - \pi_2$ varies from 20 lb. to 60 lb. per inch width of belt; therefore the slipping $= .008$, or nearly 1 per cent. With new straps it would probably be more. With soft, elastic materials, such as india-rubber, the slipping is very much greater. In some instances I have been able to make the driving pulley A turn twice as fast as the pulley B, simply in virtue of this expanding and contracting on the pulleys. This shows at once how it is that elastic straps, such as can be made of soft india-rubber, have never come into use—a fact which is otherwise somewhat astonishing, considering for how many purposes an elastic connection of this sort would be useful. A similar explanation to the above may also be given for the friction occurring when elastic tires are used for the wheels of carriages and engines. The tire is perpetually expanding between the wheel and the ground. As the wheel rolls on to the tire, it is continually elongating the part between it and the ground which is in front of the point in which the pressure is greatest. This elongation can only be accomplished by sliding the tire over both the surface of the wheel and the ground against whatever friction there may be; and similarly, towards the back of the wheel, the tire is contracting also against friction. Even when there

is no tire, if either the wheel or the ground is elastic a similar action takes place; and hence we may probably explain what is usually called rolling friction, which has been observed to take place no matter how true or hard the surface of the wheel and the plane on which it rolls may be.

THE BAIE VERTE CANAL AGAIN!

By THOS. GUERIN, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

I HAVE read Mr. Herschel's communication to this Magazine of February last, which is intended as a reply to my article of January previous. He alludes to the errors contained in his late paper, and attributes the cause to the school in which he was trained; that school having never taught him to use units of more than one denomination.

With the exception of one passage, he does not attempt to dispute the accuracy of what was shown in my article of January.

In questioning the accuracy of that passage, he says: "How the table on page 56 of this volume of this Magazine is found, is still not clear.

"For example, if $v=n\sqrt[3]{r}$, certainly when $v = 76.10$ feet per minute $= 1.302$ feet per second, and $r = 1.612$ feet per hour, the $n = \frac{v}{\sqrt[3]{r}} = \frac{1.302}{1.173} = 1.109$, instead of 0.550 as given, and similarly:

"For $v=38.56$ feet per minute$=0.643$ feet per second, and $r = 0.945$ feet per hour, it would seem that n should equal 0.655, instead of 1.327 as given, all of which may be noted by future investigators."

Here, again, Mr. Herschel is in error as usual; for the table to which he alludes is entirely correct. I refer him to page 253 of Beardmore's Manual of Hydrology, from which the table was constructed. This is his own favorite book; it having been his chief dependence in his late attempt to annihilate myself; it is, therefore, reasonable to suppose he ought to be thoroughly acquainted with it. He will find it there stated that the mean velocity of the flood stream below New Shot Isle is 78.10 feet per minute, and the average velocity above New Shot Isle is 38.56 feet per minute.

The geography of the place will show him that Glasgow and Clyde Bank are above New Shot Isle; while Bowling and Port Glasgow are below.

His equation then will run thus: $n=\frac{v}{\sqrt[3]{r}}=\frac{0.643}{1.173}=0.550$, as already given in the table. Similarly at Port Glasgow, the number 1.327 is correct as given in the table, and not 0.655 as Mr. Herschel erroneously makes it.

"He asks: "What shall the profession do with a formula whose mainstay coefficient bobs about, according to Mr. Guerin, from 0.550 to 1.3313, and according to me (as far as I at this time think it worth while to pursue it) from 0.655 to 1.3313?"

I am sorry Mr. Herschel is unwilling to comprehend the nature of the coefficient n. Once more and finally, I refer him to pages 241 and 242 of the September number of this Magazine for 1874; also to page 55 of the January number, 1875. He will there find that n does not "bob about," that it has been theoretically shown to be a constant quantity, that experiment has shown its value to be about $1\frac{33}{100}$, and that the value 0.550 is found in a locality adduced by himself in his paper to the American Society of Civil Engineers, and is foreign to the case; but the value 0.665 is not found in any case as is shown above.

It is puerile to answer any more such criticism as this. A few words more and I shall have finished with Mr. Herschel.

I compliment him on his profound knowledge of the Calculus as evinced in his description of my journey from Canada, and it may be that some one whose penetration is greater than mine can see its application to the subject in discussion. He refers to a friendly note he says he wrote to me in order to draw

out a discussion on this subject, but it was returned by the P. O. authorities, and endorsed "not found." He forgets, however, to mention another friendly note which he did write to me, and which I received, and have answered.

This last note was written to me before the publication of my last article, and after his having read the substance of that article in manuscript addressed to "The American Society of Civil Engineers." In this latter note he made a modest proposition which I declined.

If he preferred a private discussion, why did he publish the last extraordinary article? On the whole, it is manifest he thought, in the first instance, that he had found a means of refuting the article on "The Baie Verte Canal," as published in this Magazine in September, 1874, and on no account would he forego the golden opportunity of doing so publicly. The tone of his paper has shown this; for, however friendly that strayed note may have been, his paper commences by asserting that the article was "misleading"; was "a gross Hydraulic heresy"; was "an illusion"; was "an assumption"; there was "no such law"; it was "an absurdity."

Gentlemen who have read the correspondence that has taken place between Mr. Herschel and myself, will now see that those florid assertions recoil like the boomerang on the party who has used them.

CONDENSED AIR TRAMWAYS.

From "Nature."

For some weeks the North Paris Tramways Company has been trying on the line from Courbevoie to the Arc de l'Etoile a new system of locomotion, in which the motive power is compressed air. Some details of M. Mékarski's (the inventor) system are given in the *Revue Scientifique*. It is capable of considerable developments and of varied applications, since it has solved in a very satisfactory manner the double problem of the industrial production of air condensed to very high pressures, and of the storage of the air in reservoirs intended to discharge into a cylinder placed in any apparatus whatever, at any distance from the condensing pump.

The "Voiture Automatique" of M. Mékarski is characterized by the absence of an imperial, and by a platform in front and another behind. This car carries the reservoirs of condensed air, the apparatus for distribution, and the cylinders, M. Mékarski places under the truck of the car the sheet-iron cylinders, which contain the condensed air; on the front platform is placed the distributing apparatus which the engineman works; the two cylinders are placed, as in certain locomotives, outside the framework, horizontally, and act directly, by means of a crank, on the front wheels of the car. No doubt this arrangement might be advantageously modified; but the important point is the possibility of manufacturing compressed air in sufficient quantities to be of use as a motive power.

The condensing apparatus used by M. Mékarski consists of two pump-barrels of cast-iron, placed vertically, communicating respectively with two horizontal pump-barrels, in which move two pistons worked by a steam-engine. This is, in reality, a double condensing pump, the former bringing the air to the pressure of from ten to twelve atmospheres, and the second raising the pressure to twenty-five atmospheres. The pistons act upon a mass of water which compresses the air directly and absorbs by degrees the heat disengaged by compression. By an ingenious contrivance the supply of water is continually renewed, and the temperature thus kept down. But this arrangement does not absorb a sufficient amount of the heat disengaged, a difficulty which M. Mékarski has met as follows. The external air drawn into the pump raises a valve constantly covered by a layer of water of several centimetres; besides, a large cast-iron

tube, constantly traversed by the air already condensed and the excess of water, communicates with the two vertical pump-barrels; finally, the second pump is fitted with a tap by which the heated water escapes.

In M. Mékarski's automatic car the compressed air is stored, under the truck, in sheet-iron reservoirs or cylinders. The total capacity is about 2,000 litres; 1,500 litres serve as an ordinary supply; 300 litres constituting a reserve; the remaining 200 litres are intended to serve as a brake. The air is compressed in the cylinders to the pressure of twenty-five atmospheres. On the line from Courbevoie to the Arc de Triomphe, 7,500 metres going and returning, the resistance is unusually great. In one experiment the ordinary feeding cylinders contained 1,500 litres of twenty-five atmospheres at departure, and the pressure, on arrival, was not more than four and a quarter atmospheres. The expenditure had thus been about 1,250 litres at twenty-five atmospheres for a run of 7,500 metres, or 166 litres per kilometre.

But unless it is possible to heat the air gradually during its detention, and before it reaches the cylinder, unless, in fact, the heat abstracted in condensation be restored to it, the loss of power is very great. This has hitherto been the stumbling block of compressed air engines, and M. Mékarski seems to have completely met the difficulty. He adopts as a re-heater a cylinder holding about 100 litres of water, taken from the boiler of an engine, at five atmospheres, and to obtain the maximum of effect possible, the condensed air is delivered from the reservoirs to the cylinder only after traversing the entire mass of water.

By a clever contrivance M. Mékarski regulates at pleasure the action of the compressed air upon the piston. Two hermetically-closed boxes are placed vertically upon the re-heater; their common face is formed by a caoutchouc diaphragm, in direct connection with an obturator, which opens or shuts more or less the opening which communicates between the lower box and the chamber containing a mixture of compressed air and vapor in the upper part of the hot-water cylinder. It will be seen that this orifice will be more or less uncovered according as the pressure in the lower box will be above, or not, the pressure in the lower box. This second box is itself filled with air, and constitutes a small pump-barrel, in which a large plunger piston works. The rod of the piston is a screw, and is fitted outside with a small regulator, on which the driver works. This may rapidly be made to vary the presence of the air in the upper box, and consequently the pressure be increased or diminished of the air which is delivered from the lower box to the motory cylinder.

DESCRIPTION OF A SKEW-ARCH AT HARRISBURG.

By THOMAS M. CLEEMANN, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE following description of a skew arch bridge in the city of Harrisburg, which is built on a different method to either of those mentioned in the interesting papers on the subject which have just appeared in VAN NOSTRAND'S MAGAZINE, will perhaps form an interesting supplement to them.

State Street crosses the Pennsylvania Railroad at an angle of seventy-one degrees, and, in order to avoid a grade crossing, an iron bridge was erected over the tracks, and approaches made with a slight descending grade until the old level of the street was reached. The whole of the width beneath the iron bridge is filled with tracks, and the abutments are pierced with archways to accommodate foot-passengers. To illuminate these passages, a second arch was made in the walls separating them from the tracks, the two arches meeting in a groin, both being skew and intersecting at an angle of seventy-one degrees. Mr. Joseph M. Wilson, to whom the design is due, wished the smaller arch to form a

semi-circle on the face, of a radius of five feet, and the larger arch to form an ellipse of 17 feet span, and of course a height equal to the radius of the smaller arch. If the helicoidal method of building the arch had been adopted, as was at first intended, the joints on the face of the small arch would have radiated from a point below the centre, which was supposed to injure the appearance, and it was therefore made a condition that the face joints should radiate from the centre. With this limitation, the writer was instructed to make the working drawings, and supervise the construction. It occurred to him that it would not weaken the arch to make the following modification of the helicoidal method. Whereas in that method the crossing joints are generated by a line touching, as directrices, the joints of the soffit as found from the development, and the axis of the arch, and always perpendicular to the axis; there would be no objection to taking the same directrices, but introduce the condition that the generating should be always parallel to the face, instead of being perpendicular to the axis. This makes the crossing joints portions of the surface called a conoid in Warren's Descriptive Geometry, and which may be called for distinction a helicoidal conoid. It was in this manner that the arches were built. It should be remarked, however, that only the face stones of the two arches, the groin stones, and the skew backs, were made of stone, the rest was of brick, the joints running from face to skew back according to the joints drawn on the development of the soffit.

The smaller arch will be seen to be a high ellipse on the right section; that is, one in which the vertical axis is the longer.

It may be of some interest to describe in detail the mode of forming the templets, and what were required:

1st. The Smaller Arch.

The portion of the stones first dressed was one of the beds, and for this "twisting rules" were necessary. As the twist is the same for all the stones, but two pairs of them were required, one for the stones two feet long, and the other for the stones one foot long; these dimensions of stones having been chosen for convenience. One of the rules is an ordinary straight edge; the other has the addition of a triangle on the side, making it trapezoidal in shape. A draft having been cut on one edge of the stone, and the straight edge laid upon it, another is cut at the distance of two feet (for the stones of that length) and sunk until, when the trapezoidal rule is applied, the upper edges are in the same plane, observed by sighting across from one to the other. The intermediate stone is then dressed away with a straight edge. The next operation is to find the edge at the soffit. To do this, a templet is formed to the angle between the bending face joint and the soffit crossing joint, and being applied so that one side coincides with the draft previously cut at the face, the edge is marked off with the other side.

The soffit is then dressed along the edge by means of the arch square, the straight part being applied along the generating lines of the bed. The bounding lines of the surface of the soffit in each stone are marked with a templet got from the development, and made of sheet iron or zinc, so as to bend into the surface. The face can now be cut, two edges being given. Its bounding lines are next marked with a templet constructed from the elevation. The other bed is then formed with the twisting rules, and the remaining sides with the common square. Such being the process of cutting the stones, let us proceed to the mode of forming the patterns:

In the development we find AD equal to one half the curve of the face; the

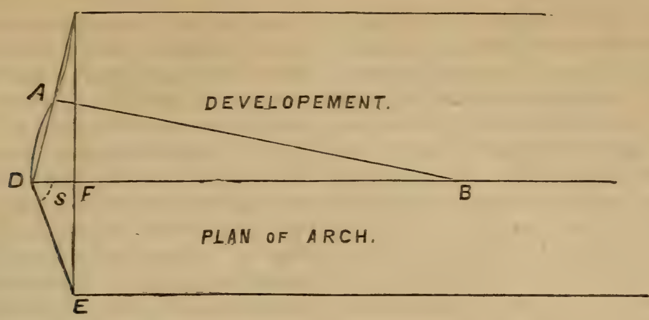
$$\text{angle } ADB = \cos.^{-1}\frac{DF}{2AD} =$$

$$\cos.^{-1}\frac{DE \cos. S}{2AD} = \cos.^{-1}\frac{10 \times \cos. 71^\circ}{2 \times 7.854}$$

$$= 78^\circ\ 02\tfrac{1}{2}'$$

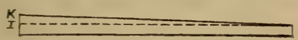
And $AB = AD \tan. ADB = 37.083$.

The generatrix of the conoidal surfaces in passing along the line AB, if there were a joint there, would describe an angle whose projection on the face would be ninety degrees. The projection of the angle described when it passed over the distance two feet on the line AB, would be the angle for the twisting rules for the two feet long stones, and one half of it, that for the one foot long



stones. We find it by the proportion, A B : 90° :: 2 : the angles required.

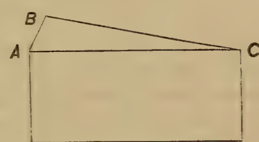
In making the rules, we assume them say two feet long; the distance I K



will be two feet multiplied by the angle found from the last proportion. The finding of the angle between the heading face joints and the soffit coursing joints, is a more complicated operation. Let us take the position of the generatrix at the face joints, and imagine a line drawn from the joint intersecting the axis at right angles; the length of this line can be found, being the square root of the sum of the squares of the abscissa and ordinate of the joint on the ellipse of right section. The generatrix and distance cut off on the axis are two other sides of a triangle, one being equal to the half span, and the other to the abscissa multiplied by tan. S. From this triangle we can deduce the angle between the generatrix and axis. We now take a second triangle in which one side is the generatrix in its primitive position, another is the length cut off on the axis in its progression to its second position, being in the same ratio to two as D B is to A B; and the included angle is the supplement to the angle between the generatrix and axis, just found; we then find the third side of the triangle. We are now prepared to find the angle required, it being in a triangle whose three sides are known; one being the side of the triangle just found, another the generatrix in its second position equal to the half span, and the third, the length of the stone, supposed two feet; the angle between the two feet side and the generatrix is the angle between the heading and coursing joint required. It is necessary to repeat this calculation for each angle of face stones.

The arch square is a piece of wood cut to the form of the soffit, with another piece attached in the direction of the radius produced. The mode of obtaining the templets for the soffit from the development, and for the face stones from the elevation, require no explanation. Two sides of these templets were made three-sixteenths of an inch less than the drawings gave, to allow for the mortar in the joints.

The skew-back stones were made in the present instance to run far enough into the arch to catch two courses of brick.



The dimensions of the shoulder are easily found

$$B\,C = \frac{A\,B}{\tan.\ B\,C\,A} = \frac{\text{thickness of two bricks}}{\text{cot. } B\,A\,C \text{ known from the development}}$$

$$A\,C = \sqrt{\overline{A\,B}^2 + \overline{B\,C}^2}$$

The student of descriptive geometry would be surprised, perhaps, that the tedious operation of solving three triangles for finding each angle between the face joints and coursing joints was pursued, when the projections can be easily constructed upon the drawing, and finding the angle is then one of the simplest problems of descriptive geometry. The writer adopted the method of calculation, partly because his drawing was small, and he has small confi-

dence in his own ability to draw with sufficient exactness, and partly, probably, from an innate love of accurate calculation whenever he finds it possible. His mathematical attainments were, however, sorely tried, and his ability found completely at fault when he attempted to calculate the requisite templets for the larger arch.

2D. THE LARGER ARCH.

Being compelled to apply his descriptive geometry to finding the necessary bevels for this arch, in order as much as possible to avoid errors of construction, he determined to make the drawings full size. He therefore obtained a sufficiently large space in the Company's Carpenter Shop, and constructed the projections on a prepared floor. Having drawn the ellipse, and marked on it the positions of the joints and measured their abscissas and ordinates, the distance from the centre to the successive points where normals to the ellipse would cut the major axis, were calculated by the formula in analytical geometry, and the joints drawn accordingly. The elevation of each stone was then constructed. A section was supposed to be made parallel to the face, and at a distance of two feet from it, and the projection drawn. With the help of the development, the crossing joints were drawn on the elevation, and the angle between them and the heading joints found by passing a plane through them and revolving it about its trace in the vertical plane until it coincided with it, when the angle could be measured, according to a simple problem in descriptive geometry.

The angle for the twisting rules was measured from the elevation, as well as the arch squares, and the soffit patterns from the development.

JAPANESE LACQUER WARE.

From "Journal of the Society of Arts."

The export of lacquer ware, though not attaining to any very high figures, is a somewhat prominent feature in the productions of Japan. Mr. Robertson, the Consul at Kanagawa, states that the lacquer ware that finds a sale in foreign markets is, as a rule, that description into which a preparation of gold powder enters, and known to Japanese as "makiyé"; but, as many articles of daily household use in Japan are of plain lacquered ware, that is, without ornament, the material of wood with a coating of plain lacquer or varnish, the industry, whether looked at as affecting the export trade, or regarded as a permanent industry in the country, and one giving employment to many hands, can not fail to commend itself to those interested in Japan and its productions.

The groundwork of lacquer consists in the sap of the "urushi" tree, the fruit of which produces the vegetable wax. The Japanese distinguish between the male and female tree, the former bearing no fruit. The trees attain to a height of from 36 to 42 feet. In those parts of the country where the trade in lacquer is of any importance, the varnish is taken from the tree when it has attained to an age of from four to eight years. On attaining the latter full age the tree is cut down. Where the tree is cultivated for the sake of the wax, the sap is not extracted; and in Aidgu and Yonegawa, where the trees are specially reserved for wax, they will be seen to attain to no inconsiderable height. The "urushi"—lacquer varnish tree—is cultivated in two ways; either by sowing or by cuttings. In following the former, the front of the tree is lightly pounded in a mortar, so as to remove the rind from the seed. These are then mixed with wood ashes, moistened with water, and afterwards put into straw bags, over which liquid manure is poured, other bags are then left to soak in water until the close of the winter. Just before the commencement of spring, on a day duly noted on the Japanese farmer's almanac, the seed is sown broadcast over the ground, and slightly covered with earth. In respect to slips or cuttings, they are

planted out in rows, and thinned as soon as a leaf or two appears. Sowings, are, however, preferred, as it is found very difficult to rear from cuttings.

The amount of varnish obtainable from any one tree depends on the vigor of the tree and the quality of the soil. A good vigorous "urushi" will, after four or five years growth, have a stem of about six inches in diameter. The sap is generally drawn off on the tree attaining its fifth or sixth year of growth, and this is done in the following manner :—A lateral incision is made with a knife in the trunk of the tree, and four days later the incision so made is punctured. The sap that exudes is then carefully removed with a small spatula, and put into a wooden jar. One incision is made at a time, commencing from the root upwards, and the trees are taken in turn. This is continued until each tree exhibits a series of cuts all up the trunk. The tree is afterwards felled. The drawing off of the sap is begun in the middle of the summer and continues to about the month of November. The very first and last sap drawn is not considered of good quality. The best is that which is drawn off late in the summer. From spring to summer the sap ascends the tree, and afterwards descends. The expert is therefore guided by this fact as to where the incisions should be made. When the sap is descending in the trunk it is considered inferior. The bark of the larger trees being somewhat thick, the ordinary instrument in use sometimes fails to make proper incision, in which case the bark is first removed prior to making the incision. The "yamo urushi," on wild varnish, grows plentifully, and in leaf and flower resembles closely the "urushi," but it meets with little attention, as its yield of sap is very small. There is also a species known as the "tsuta urushi," or ivy lacquer tree, which attaches itself to trees after the fashion of ivy, but yields even less sap than the lacquer tree. Lacquer is obtained largely in the eastern portion of the empire, but to no great extent in the western provinces. The wood of the "urushi" tree being exceptionally good, is applied to many uses, and notably to the making of floats for fishing-nets.

Having thus given a brief description of the manner in which the lacquer varnish is obtained, Consul Robertson furnishes a few additional remarks upon the preparation of the lacquer ware. The Japanese, it seems, give the year A. D. 724 as the date when the art of lacquering was first discovered, but those amongst Japanese who have given attention to the subject fix the date at the year A. D. 889 or 900. It would appear to have attained to some perfection in the year 1290, for the name of a distinguished painter in lacquer who lived at that time is still handed down as the founder of a particular school of art in lacquer painting. From that time it developed until it attained its present perfection. The following is a brief general description of the mode in which designs in lacquer are worked :—The first thing is to trace out on the thinnest of paper the required pattern or design, and the tracing is then gone over with a composition of lacquer varnish and vermilion, afterwards laid on whatever it is proposed to impart the design to, such as the facing of a cabinet, or other piece of work, and well rubbed over with a bamboo spatula. On the removal of the paper the material below will be seen to have received the outline. This is now gone over with a particular kind of soft lacquer varnish. When this industry is pursued in hot weather the varnish speedily dries, and consequently, where the pattern is a good deal involved, such as one representing bunches of flowers or flocks of birds, a small portion only of the pattern is executed at one time, and the gold powder, which enters largely into most of the lacquer ware for the foreign market, is applied to each part as it is being executed. For this a large and very soft brush is used, and by its aid the gold powder is well rubbed in with the lacquer or varnish. The work is then left to dry for the space of about twenty-four hours, after which the pattern is lightly rubbed over with charcoal made from a particular wood, this process securing evenness of surface. The work is then rubbed with polishing powder, and afterwards carefully wiped.

There still remains a good deal of finishing work, such as the tracing of leaves on trees, the petals of flowers, the wings of birds, and so on, according to the particular subject in hand. Into all of these gold powder largely

enters, the working in which requires a light brush and skillful hand, so as to preserve an even mixture of the powder and varnish. After this has well dried, a particular kind of lacquer varnish, known as "yoshino urushi," is well rubbed in, and the whole then polished with horn dust. The polishing process is done with the finger, and is continued until the gold glitter shows out well. A beautiful polish is said to be thus obtained. Briefly, then, the designing on lacquer ware is done thus: supposing the subject is to be a flower, it is traced out on the paper and imparted to the groundwork of wood. Gold powder is then sprinkled over the work from out of a bamboo tube, well rubbed in with a brush, and then allowed to dry, afterwards polished, and a coating of varnish applied.

This is repeated several times, until the work assumes a rust color. The veins or tracery of the leaves are marked out with lacquer varnish. Before this dries gold powder is again sprinkled over, and then rubbed in with a brush. When the surface has dried, it is rubbed over with a piece of charcoal, so as to tone down any irregularities. After that it is polished, when the flower will appear in due form.

COFFER DAMS IN THE CONNECTICUT RIVER.

By W. H. BURRALL, C. E.

Written for Van Nostrand's Engineering Magazine.

In the summers of 1870 and 1871, the firm of Hawkins & Burrall, of Springfield, Mass., built five coffer dams in the Connecticut River at that place. As there were some features believed to be new, in regard to the thickness of dams, and details of the work, a plain account of their construction and operation, may not be without value, as a record of actual experience.

The bridge of the Boston & Albany Railway over the Connecticut River, was at that time a wooden Howe truss, single track, in seven spans of about 180 feet each. The six piers were of dressed Monson Granite on a foundation of piles, driven about 3 feet apart, capped, leveled up with concrete and planked. These foundations were put in about 1838, three of them by dredging out the bottom, driving the piles and sawing off near the bottom, which was then leveled with concrete and the masonry built in a caisson and sunk. The remaining three were put in by means of coffer dams, as to the details of which no information is at present accessible to the writer. Around the piers, loose stone or rip rap had been deposited, extending out some 18 or 20 feet from the piers, all around.

The bottom was composed of sand and gravel of varying degrees of hardness, among which were strata of quicksand, horizontal or nearly so.

The depth of water varied with the location of the piers, and the different stages of the river while the work was in progress from 3 or 4 to about 18 feet. The current was slight at that stage of water, not sufficient to form any obstacle to the work. The bottom of the bridge was about 28 feet above low water mark.

It was desired to replace the bridge by a double track, iron structure, and to do this, the piers were to be lengthened 20 feet on the south or down stream side. To secure a good bond of the new and old masonry, the ends of the piers were to be taken down, entirely to the foundation. A new foundation similar to the original one and in continuation of it was to be put in, which required removal of the rip rap at that end and some excavation.

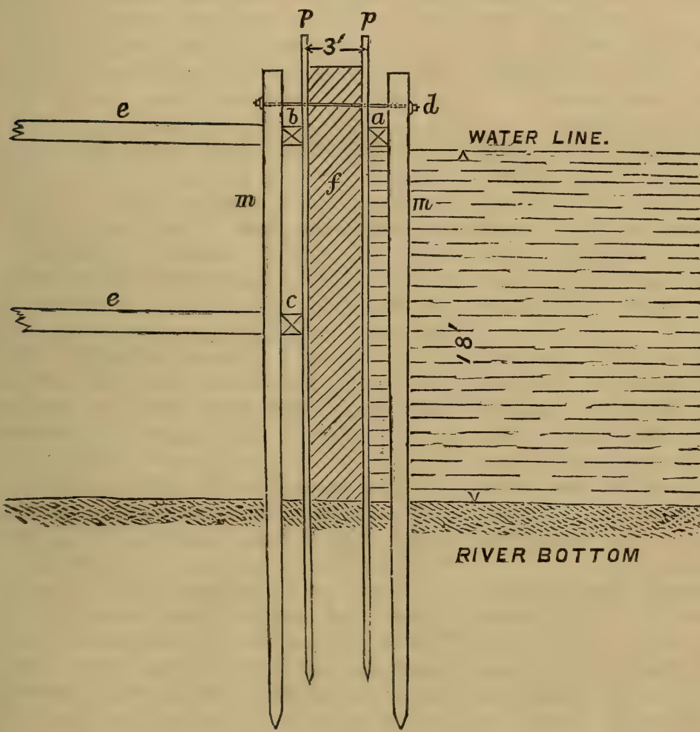
These conditions precluded the method of sinking the masonry in a caisson or by screws, which would be the natural course for a new foundation, and rendered the removal of the water necessary.

Though the bottom was one of the most unfavorable kind, it was believed

that a coffer dam of sheet piling furnished the most available mode of construction. The main danger seemed to be (as really proved the case) the veins of quicksand passing under the dam at all depths, and as no thickness of dam would obviate this danger, it was determined to build a much thinner dam than any authority could be found for, trusting to that merely to prevent *through* leakage, and dealing with the other difficulty as might seem best at the time, by dumping earth or sand bags outside, or additional sheet piling.

Another consideration was the difficulty and expense of procuring material for filling, which had to be brought on the railroad and dumped from the bridge above. The resistance to outside pressure was to be obtained by struts from the pier to inside of dam. It was decided then to drive two rows of 4-inch spruce plank, three feet apart, supported by outside piles and horizontal string pieces, on both sides, at intervals of about eight feet.

The plant for driving was as follows: A scow was built 18 feet wide, 50 feet long, and 2 feet deep inside. The sides and a parallel middle rib were made up



p p Sheet Piling.
a b′ c String Pieces
f Filling.
e e Braces to Pier.
m m Main Piles.
d ¾″ Bolt.

of two pieces Southern pine, 6″×12″, bolted together edgewise, and the whole cross planked with 3-inch spruce plank. It was entirely decked over and caulked and pitched so as to be water-tight. On the stem was placed the portable engine with drum and winch heads, and on the front end two pairs of gins, projecting slightly over the end, and three feet apart centre to centre. One hammer or monkey weighing 140 lbs. was used for driving the main piles, and for the planking, two were cast with a hollow centre, into which was driven a piece of seasoned white oak, to strike the plank. These weighed about 800 lbs. complete.

The manner of driving was as follows: The plank was sharpened on two sides, and the outer edge, had a pair of cast iron lugs, about 4 inches square, bolted on near the edge to project over and embrace the plank last driven. These were about 6 feet from the top and kept that in line.

It was then hoisted into the gins and the bottom entered between a pair of movable jaws at the foot of the gin, which reached by and embraced the plank last driven. Two planks being thus entered, the screw and plank were forced against the dam by lines from the dam to windlasses on the scow and successively driven to place. Once in ten feet the main piles were driven outside the plank.

In this way the dam was completed till the stem of the scow came in contact with the part completed. The scow was then turned at right angles to the dam, and by means of the projection of the gins from the scow and the hammer from the gins, a plank held flat against the gins could be driven, thus first the inner, then the outer row was put in, till the opening was closed.

The working gang was generally, one foreman, one engineer, one man in gins, two to tend lines, two to supply plank. About fifty to sixty plank were driven in a day, taking forty to fifty blows each to force them to a depth of 6 to 9 feet into the bottom, they being generally driven till the upper end showed signs of splintering.

The planks being all driven, battens of ½″ boards were pushed down on the inside wherever any large cracks were apparent, and nailed to the plank. The lower row of inside string pieces (*b*) were then put in, by springing the tops of the piles away from the dam, and pushing the string pieces down under water, between the piles and dam.

The upper rows on both sides were then put on and the tops of the piles drawn firmly together by the bolts (*d*). Struts were then put in between the pier and inner string pieces, and the dam was ready for filling. When the water inside was low enough, struts were also placed against the lower row of string pieces.

Less than a mile east of the bridge, the R. R. Co. were lengthening a side track through a cut some 10 feet deep. This was found to be composed of strata a few inches thick, of a tenacious clay, and nearly pure sand alternately, in about equal quantities and was at once adopted for filling. Shutes or troughs were placed from the bottom of the bridge to the dam, and the material dumped from gravel cars on the bridge, and distributed by shoveling. The dam being filled, pumping was commenced. A boiler and reciprocating steam pump placed on the dam was used at first, but much trouble was experienced from choking of the valves by sand, etc. Later a horizontal centrifugal pump was placed in the dam at the bottom, which gave perfect satisfaction, raising a 7 inch stream, 20 feet, and discharging sand, stones &c. with perfect freedom.

Meanwhile the scow and gang were driving the next dam.

Not to enter into too much detail, the general experience in pumping out was this. By the time the water was reduced 5 or 6 feet below the level outside, a "wash in" would occur, coming up in a volume of water and quicksand in some part of the included area, usually not far from the dam, and at the same time the filling in the dam would sink away entirely for 15 or 20 feet in length, over the place, and disappear, leaving the bottom inside the dam lower than, or level with, the bottom outside. No disturbance would be apparent outside, showing that the influx was through some vein of quicksand entirely below the dam. The filling sinking into the vein below would cut it off, and when that part of the dam was refilled no further trouble would occur at that place. At several of the piers, two or three "wash ins" of this kind comprised the whole difficulty.

A more troublesome variation several times took place however, when the "wash in" was so near the bottom of the dam, or so violent that it undermined and displaced the sheet piling. This was remedied by driving an additional row of plank, 3 feet outside the old ones and filling again, which always proved effectual. One of the most obstinate leaks was found to be produced by a bar of railroad iron lying transversely under the dam in the river bottom. In one case the break took place just opposite the pump which was covered some feet with quicksand. By raising it, (the centrifugal pump) on top of the sand and gradually lowering, sand and all was pumped out.

When the bottom was exposed, water would be found coming up in various places, over the enclosed area, but in no case greater than could be exposed by

the pump. The excavation for foundation was then easily made, piles driven, the new foundation completed and masonry laid.

After the masonry was above water, the planks were pulled up, and most used a second, and many a third time. The pulling up was effected by slinging a heavy four-fold tackle to the gins, and leading the fall to the engine. The first pull would generally bring the end of the scow some inches under water, but by holding on a few moments the plank would let go and come.

It would seem then, from this experience, that when a coffer dam can be braced from the inside, which may generally be done, a much less thickness may be employed than is usually recommended. This, however, depends greatly on the character of the material used for filling, and four feet would probably be preferable to three, though little or no trouble was experienced in this case from any leakage through the dam itself. The employment of cast lugs, easily applied and removed, was a very satisfactory substitute for tongueing and grooving, and the double pile driver and method of driving arose naturally from the character of the work, and seemed to meet every requirement.

THE MANUFACTURE OF CAOUTCHOUC—AND ITS INDUSTRIAL USES.

By EUGENE PAVOUX.

From the "Universal Review of Mining."

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity in an ordinary temperature. This special quality, to which it owes its repute, disappears almost entirely under a temperature approaching to that of melting ice, and only re-appears when the india-rubber is subjected to a heat of from 30° to 40°, when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends by taking the consistency of treacle. This sensibility to the influence of the temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200° it is decomposed, and passes off in a volatile form.

Its density varies between 0.925 and 0.950.

According to Faraday, it is composed of 87.2 of carbon and 12.8 of hydrogen.

India rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia Cahucha*, &c. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, &c.

It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india rubber) is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay are made in the shape of pears, which are plunged into the liquid, and afterwards made to pass over a fire made of the branches of trees, in order that the layer of india rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The pears are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited

and agglomerated; in this case, the mass of india rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india rubbers are those which are gathered in this way; such are Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption. When they are very thin they are rolled up like a skein of thread, and the appearance of the india rubber in balls serves to remind one of a clue of worsted.

In these different states india rubber arrives in Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, &c., which have become mixed with the gum whilst running from the tree. This is the object of the first process in the manufacture. The raw material, after being softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a-half, then flattened between two cylinders, horizontally placed, the distance between which is regulated at will by attachment screws. These cylinders are of different velocities; it follows, therefore, that, independent of the pressure which the india rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and, under the continuous action of a stream of water, are easily carried off. Under this process, which is repeated eight or ten times, and every time bringing the two cylinders nearer together, all the impurities vanish, and it assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a *devil*, which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp pointed teeth and disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute carries along with it the grained sheet of which we have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The *devil*, as it is called, is usually formed of a double casing, which is heated by means of a steam jet. I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, whilst if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, which deteriorates its quality and interferes with the following operation.

On leaving the *devil*, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of attachment screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are

heated internally with steam by a pipe running through a padded box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close and exceedingly smooth. This gives the finish to the preceding operations.

India rubber is only used for certain special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they have to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india rubber its various shades of gray, black, red, &c., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, whilst in the second, it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for so many purposes, amongst others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these the india-rubber paste is put into a mould, which is filled more or less correctly. The exposure of this mould to a temperature varying between 125° and 150° causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water is introduced, which, in being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of *vulcanization*. The shape then (with exception of the cutting up of certain objects into sheets) should always be given previous to vulcanizing, which is the last process of manufacture.

Raw india rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, so sensitive to the variations of heat, must have the effect of preventing those grave inconveniences arising out of it, and of making india rubber a sub-

stance that can be utilized under any conceivable circumstances. That is the object attained by *vulcanization.*

The agent employed for vulcanizing is sulphur. Its action on india rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated by a temperature of about 200°, produces a substance which offers a good deal of resistance, and which presents almost the aspect of india rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with heat; it preserves its ělasticity, resists acids, and can no longer be made either to dissolve or to stick.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the re-action to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india rubber paste, which still continues to stick. The article which is being made is put into a boiler, made of sheet iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150°. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed of two hollow, horizontal planes, the uppermost of which is movable, and worked by screws which allows it to work up and down. The moulds are placed between these two planes, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them, and which has been brought there by pipes placed at one of the extremities, and which rises to the other end through outlet pipes.

I have had fixed in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the planes are about 7 feet long by 4 feet wide, their internal surface being carefully planed and dressed gives to the sheets a glossy appearance, with remarkable uniformity of thickness.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur deposited on the surface to crack, after which it is easily removed by simply scraping it.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger volume must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphuret of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only ar-

ticles that are not very thick that can be subjected to this process.

It is exactly the same as regards the process which consists in the use of alkaline sulphurets; the operation lasts about four hours. In consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india rubber, no better agent can be employed than sulphuret of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation, leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely adandoned.

Before proceeding to treat of the industrial uses of india rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is larger, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one and demands a great deal of care to prevent the article being burnt, which, in that case, would become worthless.

Indurated india rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute." (*)

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes, may be classed in several categories, and are all practicable with india rubber. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one on several cloths dipped in the paste, and intended to prevent the lateral extension which would take place in pressing the surfaces together, as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from 2 to 3 millimetres. The same result may be obtained with felted india rubber, that is to say, mixed with fibrous matter, such as woolen or cotton waste, &c., which, by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe it prevents the waste water from running off; it is better, therefore, to adopt the system where the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes, are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

India rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of wash-

* A. Stevart: "Results of Experiments in the Elasticity of Vulcanized India Rubber."

ers of rectangular shape about 2 inches in thickness, separated from each other by sheet iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the material. To allow the passage of the buffer rod, these washers are pierced into the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoating of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In the tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their great base; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion excessively smooth and gentle. The tenacity, strength and duration of the springs depend on the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagonettes belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories entrepots, &c. In this case, the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appears to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The clappers vary in form as well as in thickness; some are round, others are square or rectangular.

The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These clappers are, for the most part, made of simple india rubber, but sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india rubber is that which has been made by M. Field, in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by the metallic pieces which retain them, in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley Partners, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

As regards pumps which are intended to pump acids, an india rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india rubber, replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India rubber is well adapted for the clappers of blasting machines. The firm of Cockerill, at Seraing, use it for that purpose in their works for the manufacture of Bessemer steel. These clappers, which have to do an enormous quantity of work, last from three to four weeks, notwithstanding the eminently unfavorable conditions under which they work, and the immense wear and tear to which they are subject.

India rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, &c., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades, worked by hand. To prevent the paste from adhering to the mandrel, care is taken to do it over first with powdered talc. Sometimes several strips are placed one on the top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows:—A round of india rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have: this number of folds depends on the diameter, and increases generally with it. The outer envelope is in india rubber, so that the pipes represent rounds of cloth completely steeped in paste. By increasing the number of rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be inhaled, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure, added to the internal vacuum, would inevitably cause. For this purpose a spiral is used, made either of galvanic iron or copper, which is either simply placed in the interior of the tube, or is embedded in the thick part of the rubber. Generally, the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for fire engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are put into a vehicle which runs on rails, and put into a boiler 20 yards long, specially prepared for them.

A particular kind of pipe is made of tanned hemp, with an inside casing of india rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of $1\frac{3}{4}$ in. will bear a pressure of fifteen atmospheres, and one of $\frac{3}{4}$ in. will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, &c.

The ropes used for wadding, which are made of cloth, done over with india rubber are made without core, that is to say without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its

turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather. They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and that they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India rubber has been used for some time for covering metal rollers employed for sizing and finishing cloth; wooden rollers are replaced by metal ones, which prevents the necessity of using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woolen cloth for the external covering of the roller, one or more sheets of india rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizing in other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of those protuberances caused by the crossing of linen or woolen covers presents a perfectly smooth and regular surface, and gives greater uniformity to the sizing. In short, the size not being in contact with the fire, in consequence of the impermeability of the rubber, there is no fear of any of those re-actions which might happen with certain coloring matter.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, one surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side slips by using india rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable, we need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, &c., &c.

As regards the application of indurated rubber, we may mention the rollers for spinning frames made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

In telegraphy, isolating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of $2\frac{1}{2}$ millimetres, so as to cut off the electric current.

If we were to point out all the applications of india rubber to surgery and ordinary uses, we should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

REPORTS OF ENGINEERING SOCIETIES.

Society of Engineers.—The first Ordinary Meeting of the Society of Engineers for the present year was held on Monday evening in the Society's Hall, Victoria Street, London. At the conclusion of the ordinary routine business, the retiring president, Mr. J. H. Adams, presented the premiums of books which had been awarded for papers read during the past year. Mr. Adams then retired from the chair, and introduced the president for 1876, Mr. Vaughan Pendred, who proceeded to deliver his inaugural address.

After commenting briefly on the satisfactory position of the society's affairs, Mr. Pendred went on to say that he had met with no small difficulty in finding a subject for his address which had not already been ably handled by his predecessors, and that the subject which he had finally selected was one which, if it presented no other merit, was at least comparatively novel. They had all heard a great deal, no doubt, of a subject very interesting to biologists, namely, Man's place in nature. He hoped they would give him a patient hearing while he said something concerning the engineer's place in nature. Mr. Pendred then proceeded to define what an engineer was, and went on to explain that the engineer's place in nature was that of the great civilizer. He pointed out that nearly all the natural comforts of modern life were due to the engineer, and he then pointed out that the engineer had great privileges and grave responsibilities. One of the privileges was that he alone could supply the soundest investments for the great mass of capital now lying idle to the great injury of trade in this country. He then expressed his opinion that engineers in Great Britain had during the last year or two manifested less energy than was desirable in supporting new engineering works, a circumstance originating, no doubt, in false delicacy, and certain to operate injuriously on the best interests of the nation. The privilege of the engineer was to find employment for money in developing the revenues of his and other nations, and so advancing civilization. The responsibilities of the engineer were defined by the fact that unless he exerted himself energetically, much suffering and disease and want of civilization must continue to exist. The engineer alone could improve the mutual economy of the world, and if the world was to be happier and better, the engineer, and the engineer alone, could produce that result. He might be asked what the engineer was to do, but he would not attempt to lay down principles of action which would suggest troubles to thoughtful members of the profession. He might point out, however, that a great necessity of the day was the improvement of the water supply of our towns and cities, and that this work required the best attention of the profession, which would find plenty of work in supplying the want. The regulation of our rivers, so as to prevent floods in winter, and to secure storage of water in summer was another great work. But the greatest of all was the cleansing of the country by an efficient method of dealing with sewage. After alluding to experiences in coal-pits and the construction of harbors of refuge as eminently claiming the attention of engineers, Mr. Pendred finished his address with a hope that when he resigned the chair to his successor, it might be found that if he had not merited the praise of the Society of Engineers, it would at least be found that he had not deserved their censure.

Royal Scottish Society of Arts.—A meeting of the above Society was held lately in Edinburgh, Mr. John Milne, President, occupied the chair. Dr. Walter Scott Carmichael read a paper entitled "A Description of the Patent Breakwater Steamer," invented and patented by himself three years ago. The ship consists of a nearly flat-bottomed hull, the sides below the water-level being nearly perpendicular, but several feet above the water-line these sides are continued with an inward slope, eventually becoming a roof over the main deck. At a distance of seven or eight feet above the main deck the sloping roofs end in a flat horizontal, partly glazed, to allow the more violent waves to pass harmlessly from windward to leeward. A spar deck above the horizontal roof affords facility for working and steering the vessel, the moving power of which is intended to be one or more propellers, working in tubes, which run from stem to stern of the ship. Dr. Carmichael expects that his breakwater steamer will advance straight through the waves instead of rising over them, and hence greater steadiness will be secured than in the case of ordinary ships. Mr. D. C. Mudie, founder, in the course of the discussion which ensued, expressed the opinion that Dr. Carmichael's steamer was, as nearly as possible, like the shape of Noah's Ark, which for carrying power and stability was the best shape of vessel yet invented. The paper was remitted to a committee to report. Mr. T. B. McFadzen followed with a paper, communicated by Mr. C. J. Henderson, on a new system of heating churches and other buildings. The system, it seems, had been applied by Mr. McFadzen to a church in Grahamstown. A small chamber is erected at the end of the church with an opening from the building itself. In this chamber the stove is placed and the smoke pipe carried into and through a fire clay pipe, which is led up through the gable towards the roof, where the fire clay pipe opens into the church and the smoke pipe is continued to the roof. The heated air in the stove-room flows up the fire clay pipe to the ceiling of the church, a circulation being produced by the cold air rushing from the church into the stove-room. It is necessary that the whole of this process be accomplished before the congregation assemble, and the heat must then be diverted elsewhere or the fuel in the stove withdrawn. On the congregation leaving, the process is re-commenced, with the difference that fresh air from the outside is supplied to the stove, and the doors of the church are left open to allow the foul air in the building to escape. Dr. Stevenson Macadam pointed out that there was no provision for ventilation from the outer air during the time the people were in church, and that in a short time the vitiated air breathed by the congregation would be breathed over again. This view seemed to be concurred in by other members.

Institution of Civil Engineers.—The paper read was on the "Holyhead New Harbor," by Mr. H. Hayter. Between the years 1835 and 1847 the attention of Government had been directed to the importance of providing improved harbor accommodation on the coast of North Wales, to facilitate communication with Ireland, and when the bridging of the Menia Straits by the Chester and Holyhead

Railway Company became no longer a matter of doubt, Holyhead was selected as the most suitable place for the packet service, as well as for a harbor of refuge. Of the several schemes proposed, the plan suggested by the late Mr. Rendel, past-president Inst. C.E., was ultimately accepted, and was sanctioned by Parliament on the 22nd July, 1847. It comprised a north breakwater, 5360 ft. in length, and an east breakwater, about 2000 feet in length (inclosing an area of 267 acres of available water space), and a packet pier, 1500 feet long, within the area. The east breakwater and the packet pier were subsequently abandoned. But it was found, as the works advanced, that the harbor was likely to prove too small, even for refuge purposes. The Lords of the Admiralty therefore decided to lengthen the breakwater to 7860 feet from the shore, to shelter a roadstead of 400 acres of deep water. The north breakwater consisted of rubble stone with a substantial stone superstructure. To convey the stone, nearly 2½ miles of single line of railway were constructed, besides other preliminary works, the total cost of which had been £92,000. The rubble mound was of great size—the average depth of water at low-water spring tides being 40 feet, and the greatest depth 55 feet—the variation of the tide at ordinary spring tides being 17 feet, and at equinoctial spring tides 20 feet. At the level of low water the mound was nowhere of less width than 250 feet, and in 50-feet depth of water it was about 450 feet wide at the base. It contained altogether about 7,000,000 tons of stone. The rubble mound having been formed, and consolidated by the action of the sea, the superstructure of massive masonry was erected. This was principally of quartz rock from the quarries, the plinths, cornices, parapets, paving, copings, and other ashlar work, being of Anglesea limestone. The work was set in lias-lime mortar. The foundations were laid at the level of low water, for which purpose the loose stone of the mound had to be excavated. The wall was built near the inner edge of the stone deposit, to allow as long a foreshore on the sea as possible, and had been carried up to a height of 38 feet 9 inches above low water to the level of a promenade, which was surmounted on the sea side by a parapet. At 27 feet above high water there was on the harbor side of the breakwater a quay 40 feet wide. The head of the breakwater was 150 feet long and 50 feet wide, founded on the rubble mound at 20 feet below low water, and was for the most part of ashlar masonry. The cost of the north breakwater and works connected therewith, including land, had been about £1,285,000, and per lineal foot about £163 10s. The cost of the stone deposited in the rubble mound had been 2s. 3d. a ton for the first portion of the break water, and 2s. 7d. a ton for the last 2500 lineal feet. The cost of the superstructure alone, excluding the head, had been £36 a lineal foot.

IRON AND STEEL NOTES.

The High Antiquity of Iron and Steel—By St. John V. Day.—With regard to Indian iron manufacture I have, in the first place, to correct an error I formerly made as to the date and place of the Iron Laht at Delhi. From all that I could then gather it seemed to belong to a period ranging from the first to the fourth century of the present era; but since that time Lieut. Cole's magnificent work on ancient Delhi, of the existence of which I was not then aware—indeed it does not appear to have been published at the time my paper, which especially referred to the Laht, was written—has come under my notice.

The iron column instead of being situated where I formerly stated is, I now find, in the axis of the colonade of the Masjid-i-Kutb-ul-Islam.

M. Garcin de Tassy has translated the Persian account of the column written by Syud Ahmed, and has supplemented it with some weighty remarks, from which it appears to have been set up by an otherwise unknown king, Rajah Dhava, *alias Midhava*, and whilst it now seems that the forging was made in the ninth century B.C., or from 1,100 to 1,200 years earlier than I had formerly stated, yet the inscription upon it is of much later date, M. de Tassy concluding the inscription to be possibly as late as the third or fourth century of the present era, and inscribed, therefore, by a king long subsequent to its originator, who, indeed, we learn from Indian history, died in the course of its construction. I have also to add that a cast of this remarkable column is now on view at the South Kensington Museum; also, that a piece of the metal has been cut from the pillar, and this piece has both been forged and analyzed by Dr. Percy, who has pronounced it as soft *wrought iron.*

Whilst speaking of India, I cannot, however, pass over that unique collection of archaic iron and steel tools which Col. Pearse, R. A., found in excavating some tumuli at Wurree Gaon, near Kamptee, in India, which tumuli are believed to date from about 1500 B. C., or the time of Moses; and whilst we have no such solid relics of the tools used by the Hebrew race, yet we know from words in the Hebrew language that they were well acquainted with iron in all its forms, and this discovery (which, if the date assigned by Col. Pearse be correct) shows at least that the contemporary nations were well acquainted with iron and steel; that their language, too, the Sanskrit, in its oldest forms, has corresponding words for iron, iron ores, &c.

Col. Pearse has presented his "find" to the trustees of the British Museum, and I lately was fortunate in receiving from Col. Pearse himself a full explanation of the several implements, which include gouges, spatulæ, ladles, and a variety of other articles.

RAILWAY NOTES.

Big Locomotives and Long Trains.—The Harrisburg *Patriot* says: For general use the heavy engines constructed within the past few years are not considered available. Although they are much more powerful than the ordinary locomotive and consequently can pull longer trains, they are not more service-

ble. A wreck occurred on the Philadelphia and Erie Railroad a few days ago from the fact that what should have been two trains was compressed into one, drawn by one of the large locomotives. Railroad men say that where long trains are hauled the momentum is so great that when an accident occurs to a front or centre car the wreck must prove a disastrous one, owing to the tremendous weight in the rear that nothing can successfully resist. For this reason they look upon the large engine as a failure—that is so far as the object intended is concerned, that of drawing sixty or seventy cars instead of an average train of thirty or thirty-five cars.

Strength of Rail Joints.—At a late meeting in the hall of the Manchester (England) Institution of Civil Engineers, the following paper was read:

The introduction of the plain fish-plates now ordinarily used was a great advantage at the time to the railway world, mainly for preventing accidents by keeping the rails in position laterally, but since speed has increased, and weight of engines also, the plain fish-plates have been found deficient in one vital respect, viz., that of giving the rail joint the same stiffness and elasticity as the solid rail, so as to obtain one continuous road. As the stiffness of the joint with plain fish-plates principally depends upon the section of the rail and the fishing angle, often only a third of the stiffness of the joint is afforded as compared with that of the solid rail, but even in the best cases hardly more than half the rail stiffness is obtained. The introduction of steel rails necessitating the abolition of notches in the rail flange as destructive to the strength of the rail, has led to the design of the French or German fish-plate (*eclisse arret*) adapted for suspended joint, but requiring base plates at the joint sleepers. Even with this plan the experiments show only two-thirds of the strength of the solid rail is obtained, and as only one fish-plate of this description is generally used there is still less stiffness. Several other plans exist, more or less complicated, but as none have yet given the same stiffness as the rail, combined with cheapness in cost and maintenance, they have not come into general use, and the weak joint, with ordinary plain fish-plates, is still generally adopted. This has given rise to the design of the deep fish-plate for flange rails, similar to what has already been adopted for double-headed rail sections on many English railways. By using one fish-plate of this kind on the bolt-head side of the joint a material improvement is obtained, inasmuch as such joint possesses 80 per cent. of the stiffness of the solid rails. As regards the use of two deep fish-plates the experiments are conclusive as to the great increase in stiffness, being even stiffer than the rail both as regards strength and elasticity. Experiments on 2-feet supports show a load of 35-tons with more deflection on the rail than on the joint, proving a slight superiority of the joint, even in this respect best shown by the fact that the bolts were not the least hurt after such an extremely heavy test.

ENGINEERING STRUCTURES.

The Proposed Thames Tunnel.—Mr. Barlow, C. E., has had an interview with the Works Committee of the Limehouse District Board of Works with reference to the question of the communication between the north and south of the Thames, by means of a tunnel under the river. Mr. Barlow, in explaining the nature of the proposal, said the tunnel would commence in the East India Road, and, by way of Robin Hood Lane, reach the river in the vicinity of Blackwall Stairs. The tunnel would terminate on the south side of the Thames, below Greenwich Hospital. As to the gradients, they would be only at the very moderate rate of 1 in 40. Having heard Mr. Barlow, the Committee of Works passed a resolution expressing their opinion that the proposed tunnel would be a great benefit to the public, and the Board agreed to memorialize the Metropolitan Board of Works in support of the scheme.

The Albert Bridge, Montreal.—The *Montreal Daily Witness* gives particulars of the plans prepared by Mr. Legge, C. E., for the Royal Albert Bridge, which is to span the St. Lawrence at Montreal, a little lower down than the Victoria Bridge. It is to accommodate a railway track, carriage and cart traffic, and a tramway line, and provision is also to be made for pedestrians. Its total length will be 15,000 linear feet, or very nearly 3 miles. It will have one opening of between 500 and 600 feet clear span over the navigable channel of the St. Lawrence, with a height of 130 feet above the water at high tide; five of 300 feet each at the same height, four of 240 feet each, and 51 of 200 feet each. The estimated cost of the bridge is $4,000,000, and its erection, which will commence this spring, is expected to occupy three years. The Victoria Bridge, which has hitherto passed for being the largest in the world, is only 7,000 feet long, with one opening of 330 feet span, and 14 of 242 feet span. Its construction occupied six years, and the total cost was £1,260,000.

Dredging and Harbor Works—The Institution of Civil Engineers.—At the ordinary meeting of the session held on February 8th, Mr. Geo. Robt. Stephenson, president, in the chair, the paper read was on "Carlingford Lough and Greenore," by Mr. James Barton, C. E. It was stated that the mouth of Carlingford Lough was sheltered by a natural breakwater of rock, leaving a channel about 700 feet wide. Across this channel a bar of blue clay and boulders had existed previously to the works described, the depth of water being only 7½ ft. at low tide. Within the Lough the water was more than 18 ft. deep at low water over an area of 1,200 acres, affording safe anchorage. Although the cutting of a channel for navigation through this bar had been recommended by the Tidal Harbors Commissioners and by the Refuge Harbor Commissioners, it had not been carried out as a public work, but was undertaken locally under the Piers and Harbors Act, and was authorized by Parliament in 1864 to be executed by a Board of Commissioners, for which pur-

pose a sum of £80,000 was lent by the Public Works Loan Commissioners on the security of expected tolls. The exposed position of this work was somewhat unusual for dredging. The number of days in the year when the weather permitted the dredging to proceed varied from a minimum of sixty-seven in the year 1871, to a maximum of 131 in 1873, and upon many of these days the work was limited to two or three hours. The materials raised per season varied from 50,000 tons to 99,720 tons; the clay was generally blue and plastic, with boulders embedded, varying in size up to 4 tons in weight. The dredging plant had been specially designed, and was constructed by Messrs. Simons & Co., of Renfrew: it dredged in water 35 ft. deep, and lifted stones up to 30 cwt.; the larger ones were chained by divers and raised by a crane on the vessel's bow. The average lift for all days on which the dredger worked, whether one hour or sixteen hours, had been 850 tons; the maximum tonnage raised in one day was 4,000 tons. Some rock inside the Lough had been removed by first blasting on the surface with dynamite, and then dredging the broken-up rock. The channel already formed was 18 ft. at low water of spring tides for a width of 300 ft., and a further width of 50 ft. at each side had been cut to a depth of 14 ft. at low water. The channel was intended to be 600 ft. wide, and 18 ft. deep at low water The cost of the works, including insurance of plant and Parliamentary contests, &c., had been approximately 1s. 9d. per ton. The cost of the actual work for any one season varied from 1s. 4d to 1s. 6d. per ton. Two leading lighthouses had been erected to guide vessels through the channel, which was about three-quarters of a mile long. Within Carlingford Lough a point stretched out to the edge of deep water from the south side called Greenore, and here, three miles inside the bar, a marine station had been constructed and a railway to it formed from the Irish North-Western Railway at Dundalk, and another was in process of construction from Newry. This point afforded special facilities for a fixed hour steam service to Holyhead and elsewhere. The works at Greenore had been designed to provide for the convenient loading and unloading rapidly of steamers, with passengers, cattle, and goods, and to provide for the necessities of each kind of traffic.

The front of the land end of the wall below low water was formed of concrete blocks of about 3½ tons, set by divers, and the back face of the wall had been formed of concrete in sacks, containing about 1 cubic yard each, put down soft, and built in courses; and the hearting was of concrete deposited soft.

The foundation at the sea end had been formed of concrete blocks of 100 tons each, built upon the beach above low water in frames, and lifted, carried, and lowered between two barges by special machinery worked by hand. Two of these blocks, one upon the other, formed a length of 10 ft. of the wall up to low water. Above low water the wall had been built of heavy rubble limestone masonry, and it was fendered throughout. The cost of the works at Greenore had been £130,000. The cost of the quay wall, 45 ft. high on an average, had been, including extras, £27 8s. per lineal foot. The concrete used was one of Portland cement to six of sand, gravel, and stones. The cost of the concrete blocks of 100 tons each, when set, exclusive of barges and machinery, had been 30s. per cubic yard. That of the concrete built in the back face of the wall in sacks had been 23s. per cubic yard, while the cost of the liquid concrete set in the foundatians had been 18s. per cubic yard.

ORDNANCE AND NAVAL.

The Steamship Great Britain.—At a time when shipping legislation occupies the attention of many public meetings, and virtuous and indignant shipowners protest that their vessels are not rotten, but unfortunate, the following particulars of the Great Britain may be found suggestive. This famous vessel was the first iron steamer built by Brunel, and made her first voyage from Bristol to London in January, 1845, sailing from Liverpool to New York in August of that year. She is 322 ft. long, 51 ft. beam, and 32 ft. 6 in. deep, and has engines by Penn of 500-horse power. Since 1851 she has been, with the exception of her work during the Crimean war, a regular Australian trader, and has sailed over 1,000,000 nautical miles in that service, her last voyage to Melbourne being accomplished in 54 days. The vessel was surveyed recently, was found to be in a thoroughly sound condition, and to be one of the strongest vessels in the merchant service. And yet this vessel went on shore at Dundrum Bay—a spot which, we venture to think, would prove fatal to many of our modern iron-built ships.

The Mediterranean Navies.—The military contributor of the *Cologne Gazette* observes, in an article on the navies of the Mediterranean, that by far the strongest naval power on that sea is Turkey. All the ironclads of her fleet are of recent construction, and most of them have come from the best English shipbuilders. The armor of the Turkish ironclads is from 5½ in. to 8 in. thick (two of the casemate ships have 9 in. plates), and they are armed with 8-in. and 9-in. Woolwich muzzle-loaders and Krupp breech-loaders. Turkey has four ironclad frigates of 3,050 horse power and 64 guns, six casemate ships each of 700 horse power and 5 guns, and three turret ships of 1,200 horse power and 11 guns, making in all fifteen ironclads with 9,250 horse power and 116 guns. To these should be added three ironclad gunboats of 240 horse power and 6 guns on the Danube, and two ironclad gunboats on the Lake of Scutari, each with 60 horse power and 2 guns. The screw ships are also for the most part well built and equipped. They consist of four ships of the line, thirteen frigates and corvettes, twenty-two avisos, and twenty-seven gunboats and coasting vessels, besides 101 transport ships, all large and mostly well armed. The actual strength of the available fleet of Russia on the Black Sea cannot at present be accurately estimated, but the writer thinks there can be

doubt that it is far inferior to that of the Turkish fleet. Austria has four ironclad casemate ships, of 3,600 horse power and 60 guns, and seven ironclad frigates, of 4,050 horse power and 980 guns. Three of these ships, however, are now being rebuilt, and most of the others do not fulfill the requirements of modern naval warfare, either as regards the thickness of their plates or the calibre of their guns. This remark applies even more to the Italian ironclad ships, several of which are to be sold by auction this month, in order to obtain funds for constructing new ones more suitable to modern requirements.—*Pall Mall Gazette.*

BOOK NOTICES.

NOTIONS PRATIQUE SUR L'ANALYSE CIMIQUE DES SUBSTANCES SACCHARIFERES, par M. A. TERRIEL. Paris: Dunod. For sale by D. Van Nostrand. Price $2.00.

This is a separate reprint of the second part of a former work bearing the title of *Portjeuille du Sucrier.*

The present volume contains all of the former that relates to analysis of the several products of sugar manufacture.

A thin octavo of 120 pages, illustrated, with 28 wood cuts.

ANNUAIRE, METEOROLOGIQUE ET AGRICOLE POUR 1876. Paris: Gauthier Villars. For sale by D. Van Nostrand. Price 80 cts.

This is a fair treatise on practical meteorology, containing complete descriptions of the best instruments in use.

The information regarding magnetic phenomena is of the fullest possible kind, and includes a magnetic chart of France. The automatic registry of barometric variations, and of force and direction of the wind, are exceedingly well represented by diagrams.

SIXTH ANNUAL REPORT OF THE ACUSHNET WATER BOARD. New Bedford: E. Anthony.

This report of the Water Supply for New Bedford, besides the details of local interest, contains the tabulated results of measurement of the duty of the two pumping engines, extending through the years 1874–5. The engines are a Worthington and a McAlpine. The summary is as follows:

	Hours.	Cost of coal.	Gallons pumped.
1874.			
McAlpine engine,......	706	3,438	143,136,371
Worthington " ...	1,749	5,866	215,122,464
1875.			
McAlpine engine,....	509	2,685	113,278,900
Worthington "	2,431	8,180	303,665,904

TRAITE DES PARATONERRES, par A. CALLAND. Paris: Ducher & Co. For sale by D. Van Nostrand. Price $3.00.

A full-sized octavo volume, on the subject of Lightning-Rods, suggest an overdoing of the subject; yet when it is considered that to popularize the subject, the necessary preliminaries of electrical science must be presented, it must be acknowledged that an opportunity is offered to the writer to appear voluminous.

In the present treatise there is no attempt to encumber the work with useless matter; but the *theory*, *construction* and *utility* of lightning rods, is fully and fairly presented. Some suggestions for adaptation of forms of rod, and of their connections to the structures they are designed to protect, seem new and valuable.

One hundred and seventy pages of text and 70 wood cuts, are comprised in the volume.

THE INTERNATIONAL MERCANTILE TELEGRAPH CODE; compiled for the Use of Bankers, Merchants, Manufacturers, Contractors, Brokers, Shipowners, &c., and their Agents, for the economical and secret Transmission of Business Telegrams, the Ciphers being Words of ten Letters or under, to meet the Requirements of the Rules adopted at the St. Petersburg International Telegraph Conference of 1875. By the author of the "General Telegraph Code," the "Cotton Telegraph Code," &c. London: Hamilton, Adams & Co. 1876. For sale by D. Van Nostrand. Price $12.50.

No better recommendation of a book can be given than that it has passed into its thirty-third edition, which is announced of the "Cotton Telegraph Code." But as this code was mainly limited to one particular business, the author, a year or two back, submitted a second code for general use. This work, however, through some of its words having been made faulty by the rules of the International Conference, has led the author to prepare the above, which, as will be seen by the lengthy title, will meet nearly every want. Amongst other things, the compiler says of his work that it "contains nearly 20,000 sentences in cipher, applicable to all departments of commerce, and most judiciously selected; and not only is it the result of years of experience and study, but it also combines with this the numerous and invaluable suggestions received from mercantile men in all parts of the world. The sentences are, without exception, strictly of a business character, care having been taken to throw out any phrases that might be useless; and large as the number is, the author can confidently assert, that not one of them can be pointed out that is superfluous in a work of this sort. The ciphers are all plain English words, of not more than ten letters, chosen from a standard dictionary, and the greatest possible care has been taken to prevent too close a similarity; and no word, likely to be the name of a person, town, or ship has been used. Another feature of this book is, that a very large number of simple questions and answers are provided, which admit of endless combinations; and which are not to be found in any public or private code the author ever saw." This is saying not a little for the value of the book, but it is truly justified, as we have taken occasion to test. The saving effected by the code is from 75 to 85 per cent., while a mere novice can easily learn to use the work intelligently. Lastly, we may add, that words have been selected and room left for new phrases to suit purchasers, and it may be bought in sheets for interleaving or

extra copies of particular sections obtained, to prevent infringement of copyright, against which the author very significantly cautions the public.

DYEING AND CALICO PRINTING, INCLUDING AN ACCOUNT OF THE MOST RECENT IMPROVEMENTS IN THE MANUFACTURE AND USE OF ANILINE COLORS. By the late DR. F. CRACE-CALVERT, F.R.S., F.C.S. Edited by John Stenhouse, LL. D., F.R.S., &c., and Charles Edward Groves, F.C.S. London: Simpkin, Marshall & Co., 1876. For sale by D. Van Nostrand. Price $8.00.

The subjects treated of in the volume now before us possess a twofold interest—first as involving questions of pure science in the domain of organic chemistry; and secondly, as being of immense industrial importance to the country. It does not enter into our province to notice the work in its industrial aspect, but we have no hesitation in stating that author and editors have performed their task in a highly creditable manner. From every point of view the work will be found useful, and we can recommend it to the scientific chemist as well as to dyers and calico printers

The author, who died in 1873, had been occupied up to the time of his death in preparing a treatise on coloring matters other than aniline. The present work has been edited from the author's MSS. with the addition of five chapters, forming a considerable portion of the book, on the coal-tar colors, by the editors.

The mode of treatment pursued is nearly the same for each dye. The natural history and source of the material from which the color is obtained are first given, then the chemical composition and mode of preparation or manufacture, and finally the method of application to the various fabrics described. The whole subject is profusely illustrated by specimens of dyed and printed fabrics pasted into the book.

The work is appropriately prefaced by an obituary notice of the author. The first chapter treats of color in general and the action of different forces, chemical agents, &c., on the various coloring matters.

Chapters II. and III. are entirely devoted to madder dyes, and contain, among much valuable chemical information, a description of Prof. Stoke's optical tests for alizarin and purpurin. The method of dyeing in Turkey red and the action of different mordants in madder and garancin printing is clearly explained, and the manufacture of artificial alizarin described. Chapter IV. treats of the red dyewoods—logwood, sapan. Lima, peach, and Brazil woods; also of safflower and alkanet. Chapters V. and VI. are devoted to indigo—this portion of the subject being described in considerable detail. Chapter VII. contains accounts of cochineal, kermes, gumlac, lac dye, lac lake, and murexide, while Chapter VIII. treats of orchil, cudbear, and litmus. In Chapter IX. some of the important yellow coloring matters are treated of, such as quercitron, fustic, Persian berries, weld, aloes, turmeric, annatto, &c.; while tannin matters form the subject of Chapter X., the most important of these being sumach and catechu. Chapter XI. contains descriptions of the methods employed for testing and determining the commercial value of particular samples of the various dye-stuffs. In this chapter will be found described some of the different forms of "colorometers" which have been devised for estimating the coloring power of dyes.

The portion of the work devoted to the coal-tar colors commencing with Chapter XII. begins with an account of the various bodies which have been found in coal-tar. A list of thirty-eight distinct compounds is given, and many more doubtless exist. The most important substance produced in the dry distillation of coal, so far as the dye manufacturer is concerned, is benzene. The conversion of this substance into aniline is explained, and the manufacture of magenta described, the chapter concluding with an account of safranine and some other aniline reds. Chapter XIII. treats of aniline violets, and blues such as mauve, the Hofmann and methyl-aniline violets, diphenylamine, and Nicholson's blues, &c. In Chapter XIV. we have a description of the greens, aldehyde, iodine, and methyl-aniline and the aniline yellows, phosphine, zinaline, &c. Chapter XV. treats of aniline black and brown, and the concluding chapter is devoted to the phenol, cresol, and naphthalene colors, including picric acid, corallin, aurin, and others. Not the least useful portion of the book will be found the tables at the end, which consists, first of a list of the madder-coloring matters, their formulæ, and reactions, and then a series of tables, which will enable the analyst to distinguish the different colors when fixed on fabrics.—*Nature.*

LEGAL CHEMISTRY. A GUIDE TO THE DETECTION OF POISONS, EXAMINATION OF STAINS, ETC., ETC., AS APPLIED TO CHEMICAL JURISPRUDENCE. Translated with additions from the French of A. NAQUET, Professor to the Faculty of Medicine of Paris. By J. P. BATTERSHALL, NAT. SC. D., with a preface by C. F. CHANDLER, PH. D., M.D., LL. D. New York: D. VAN NOSTRAND. Price $2.00.

The names of author and translator are a sufficient guaranty of the value of this handbook. Its convenient size will recommend it to students, who are generally overwhelmed by the bulkiness of the volumes in general use. The present work without covering so much ground as the larger treatises, is so compactly written as to be an exceedingly valuable substitute for them. We append the complete table of contents:

Introduction. Methods of Destruction of the Organic Substances—By means of Nitric Acid; by means of Sulphuric Acid; by means of Nitrate of Potassa; by means of Potassa and Nitrate of Lime; by means of Potassa and Nitric Acid; by means of Chlorate of Potassa; Chlorine; by means of Aqua Regia; Dialysis. Detection of poisons, the presence of which is suspected—Detection of Arsenic; Method used prior to Marsh's test; Marsh's

test; Raspail's test; Reinsch's test. Detection of Antimony — Flandin and Danger's Apparatus; Naquet's apparatus. Detection of Mercury—Smithson's pile; Flandin and Danger's apparatus—Detection of Phosphorus—Orfila's method; Mistcherlich's method; Dusart's method, as modified by Blondlot; Fresenius and Newbauer's method; Detection of Phosphorus by means of bisulphide of carbon; Detection of Phosphorus Acid; Estimation of Phosphorus. Detection of Acids — Hydrochloric Acid; Nitric Acid; Sulphuric Acid; Phosphoric Acid; Oxalic Acid; Acetic Acid; Hydrocyanic Acid. Detection of alkalies and alkaline earths. Detection of chlorine, bromine and iodne—Chlorine and Bleaching Chlorides; Bromine; Iodine. Detection of Metals; Detection of alkaloids and some ill-defined organic substances; Stas's method; Stas's method as modified by Otto; Stas's method as modified by Uslar and Erdman; Rodgers and Girdwood's method; Prollius's method; Graham and Hofman's method; Application of Dialysis in the detection of Alkaloids; Identification of the Alkaloid; Identification of Digitaline, Pierotoxine and Colchicine. Method to be employed when no clew to the nature of the Poison present can be obtained—Indicative tests; Determinative tests. Miscellaneous Examinations—Determination of the nature and color of the hair and beard; Determination of the color of the hair and beard; Determination of the nature of the hair; Examination of Fire-arms; The gun is provided with a flint-lock and was charged with ordinary powder; The gun is not provided with a flint-lock; Detection of human remains in the ashes of a fire-place; Examination of writings; Examination of writings, in cases where a sympathetic ink has been used; Falsification of coins and alloys; Examination of alimentary and pharmaceutical substances; Flour and Bread; Fixed Oils; *a* Olive Oil intended for table use; *b* Olive Oil intended for manufacturing purposes; *c* Colza Oil; *d* Hemp-seed Oil; *e* Linseed Oil; Milk; Wine; Vinegar; Sulphate of Quinine; Examination of blood stains; Examination of spermatic stains.

The following abstract from the author's introduction, indicates some points of excellence characteristic of the book:

"The detection of poisons, although perhaps the most important, is not the only subject that may come within the province of the legal chemist; indeed, it would be somewhat difficult to define, *a priori*, the multitude of questions that might arise. In addition to cases of supposed poison, the following researches are most often required:

1. The examination of fire-arms.
2. The analysis of ashes, in cases where the destruction of a human body is suspected.
3. The detection of alteration of writings, and of falsification of coins and precious alloys.
4. The analysis of alimentary substances.
5. The examination of stains produced by blood and by the spermatic fluid.

Each of these researches justly demands a more extended consideration than the limits of this work would permit. The several subjects will be treated as briefly as possible, and at the same time, so as to convey an exact idea of the methods employed, leaving to the expert the selection of the particular one adapted to the case under investigation. We will first mention the methods used in the search for toxical substances. The poisons employed for criminal purposes are sometimes met with in a free state, either in the stomach or intestines of the deceased person, or in the bottles discovered in the room of the criminal or the victim. Under these circumstances, it is only necessary to establish their identity by means of their chemical properties, as directed in the general treatises on chemistry, or by their botanical, or zoological character, in case a vegetable or animal poison, such as cantharides, has been administered. Examinations of this class are extremely simple, the analysis of the substances found, confined to a few characteristic reactions, being a matter of no great difficulty. We will not here dwell longer upon this subject, inasmuch as the analytical methods used are identical with those employed in more complicated cases, with the sole difference that, instead of performing minute and laborious operations in order to extract the poisons from the organs in which they are contained, with a view of their subsequent identification, we proceed at once to establish their identity. The directions given in regard to complicated investigations apply, therefore, equally well to cases of a more simple nature. The detection of poison mixed with the organic substances encountered in the stomach, or absorbed by, and intimately united with the tissues of the various organs is more difficult. If, however, other information, than chemical can be obtained, indicating the poison supposed to be present, and the presence or absence of this one poison is the only thing to be determined, positive methods exist which admit of a speedy solution of the question. When, on the other hand, the chemical expert has not the advantage of extraneous information, but is simply asked,—whether the case be one of poisoning ?—nothing being specified as to the nature of the poison used, the difficulty of his task is greatly increased. Up to the present time, the works on Toxicology have, it is true, given excellent special tests for the detection of particular poisons; but none have contained a reliable general method, which the chemical expert could use with the certainty of omitting nothing. Impressed with this need, we proposed, in 1859, in an inaugural dissertation then presented to the Faculty of Medicine, a general method, which, after some slight modifications, is now reproduced. The special methods which allow of the detection of various individual poisons will, however, first be indicated. In cases where the poison is mixed with organic matter, the latter must be removed as the first step in the investigation, as otherwise the reactions characteristic of the poison searched for would be obscured. When the poison itself is an organic substance, this separation is effected by processes modified according to the circumstances. If

the detection or isolation of a metallic poison is to be accomplished, the most simple method consists in the destruction of the organic substances. The various methods for effecting this decomposition will now be described.

MISCELLANEOUS.

Tramway Locomotive.—A new tramway locomotive is being experimented with on a private tramway, at the quarries of Avron-Neuilly, near Neuilly-sur-Marne. The motive power is compressed air, mixed with steam. For a journey of three-eighths of a mile, with twenty-five passengers, a charge of 800 litres of compressed and heated air is found to be sufficient, the vehicle weighing 4,500 kilogs. The journey is made without noise or smoke, no steam is given off, and stoppage is easily effected.

Purification of Smoke.—An apparatus for washing smoke, and so depriving it of its character of a nuisance, is in operation at a factory at Ménilmontant, Paris. A fine shower of water, traveling in the direction of the smoke, and at five times its velocity, is projected into the chimney, where it mixes with the smoke, taking up the soluble gases and precipitating the impurities carried up with the smoke by the draught. The foul water is discharged into a cistern, where it is collected, and a fine black paint is got from it.

Mining Industry in Austria.—From the official Austrian report on mining we learn that in 1874, there were 1,801 mining undertakings in activity in the Austro-Hungarian Empire, classified into 370 coal mines, with 36,980 workmen; 863 brown coal mines, with 27,449 workmen; 243 iron mines, with 8,753 workmen; and 325 mineral works of miscellaneous character, employing 14,249 workmen. Austria had 227 smelting works, with 10,730 workmen, comprising 125 blast furnaces, with 9,055 workmen.

A new composition, being a bad conductor of heat, is recommended by M. S. Coline, a French engineer, for the bearings of all kinds of machines, wheels and axles, as not requiring any lubrication. The following is the recipe for the composition :—Take about 25 per cent. of abestos, and the same of plumbago, and mix them very intimately and carefully together; then add sufficient liquid silicate of soda or potash to reduce the whole to a half dry paste. The paste must then be submitted to the action of a hydraulic or other press, till it is converted into a solid mass which is afterwards dried either in a furnace or by exposure to the air, until all moisture has disappeared. The bearings may either be turned out of the block or moulded from the composition while in the moist state. When the bearing is finished it is steeped in hot melted paraffine, mineral wax, or in a solution of paraffine, benzole, or other mineral oil, until all the pores in the composition are filled up.

There is at length a fair prospect that telegraphic communication with the Channel Islands and the Isle of Man will be re-established within a very short time. The cable ship Caroline has shipped at Silvertown some twenty-five miles of new cable for the Channel Islands, to replace a great portion of the faulty cable now submerged between Dartmouth and Guernsey. Having completed this portion of her endertaking, she will proceed to the Isle of Man to recover a portion of the faulty cable submerged there, and to lay new shore ends in readiness for a new deep sea section of cable at present in course of manufacture. A month or six weeks of fine weather will probably suffice for the completion of the whole of these important operations; and towards the middle or end of September we may hope to be once more in direct communication with the Channel Islands and the Isle of Man.

Of the Annual Report of Statistics of Lowel Manufactures, the following is an abstract:

Merrimack Manufacturing Co. — Capital stock, $2,500,000; number of mills, 5 and print works; spindles, 159,464; looms, 3,941; water wheels, 6 turbines 5 ft., 4 do. 8 ft. 6 in. diameter; steam power, 40 engines, 3,800 horse power.

Hamilton Manufacturing Co.—Capital stock, $1,200,000; number of mills, 5 and print works; spindles, 56,080; looms, 1,546; water wheels, 9 turbines; steam power, 17 engines, 943 horse power.

Appleton Co.— Capital stock, $600,000; number of mills, 3; spindles, 42,488; looms, 1,202; water wheels, 5 turbines; steam power, 2 engines, 400 horse power.

Lowell Manufacturing Co.—Capital stock, $2,000,000; number of mills, 1 spinning, 2 carpet, 1 fine worsted; spindles, 19,700 worsted and wool, 2,816 cotton; looms, 297 power carpet, 75 lasting; water wheels, 2 turbines, 10 feet diameter, 1 do. 8 feet 4 inches diameter; steam power, 3 engines, 825 horse power.

Middlesex Co. — Capital stock, $750,000; number of mills, 4 and dyehouses; spindles, 13,340; looms, 230 broad; water wheels, 1 turbine, 5 breast, 12 and 17 ft.; steam power, 1 engine, 125 horse power.

Tremont & Suffolk Mills.—Capital stock, $1,200,000; number of mills, 4; spindles, 93,528; looms, 2,300; water wheels, 8 turbines, 8 feet 4 inches diameter; steam power, 2 engines, 1,000 horse power.

Lawrence Manufacturing Co.—Capital stock, $1,500,000; number of mills, 5 and dyehouses; spindles, 92,000; looms, 2,260; water wheels, 11 turbines, 9 ft.; 1 do. 80 in.; 1 do. 24 in.; 2 do. 48.; 1 do. 42 in.

Boott Cotton Mills.—Capital stock, $1,200,000; number of mills, 6; spindles, 112,752; looms, 2,552; water wheels, 6 turbines, 7 feet 8 inches, 1 do. 6 ft. 8 inches, and 2 do. 6 feet; steam power, 1 engine, 440 horse power.

Massachusetts Cotton Mills.—Capital stock, $1,800,000; number of mills, 6; spindles, 101,720; looms, 2,808; water wheels—diam., 3 turbines, 10 ft.; 2 do., 9 ft.; 1 do., 6 ft.; 4 do., 5 ft.; steam power, 1 engine, 200 horse power.

Lowell Bleachery.—Capital stock, $300,000; number of mills, bleachery and dyeworks; water wheels, 1 turbine; steam power, 2 engines, 1,050 horse power.

VAN NOSTRAND'S
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THE PROFILES OF HIGH MASONRY DAMS.

BY JOHN B. McMASTER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

III.

The second modification, then, of the theoretical profile of equal resistance, consists in replacing the outer curved face by a broken one composed of two planes inclined at different angles to the horizon. The principles, however, which justify us in the use of such a modification, may be carried still further, and the inner and vertical face replaced by one almost a fac simile of the outer broken one. Indeed the only essential difference between them lies in the degree of slope which we give to their two plane surfaces. On the one side both are sloping; on the other that portion of the face from the summit of the dam to a point below, (where the pressure on each unit of surface equals the assumed limit of pressure,) the wall is vertical, and from here to the base slope outward. This latter point moreover, must be directly opposite that point on the outer face at which the two sloping lines of the profile intersect. Of a profile thus constructed, some idea may be had from the sixteenth figure. It does not present any merit either as to beauty, strength, stability or economy of material not possessed by that illustrated in Figs. 12 and 13. As to economy indeed, the amount of material consumed is if anything greater in former than in the two latter forms of dams, and it may be justly doubted whether the additional stability thus obtained, is a fair recompense for the additional outlay for material and for cutting facing stones for a third sloping face.

As to the mathematical calculations of such a profile they are rather lengthy than difficult. For the upper portion A B C D, we have already discussed at length the principles, and obtained in equations 51 to 55 the necessary formulæ. The value of A B or b is of course known, as also that of A D or a' which is assumed, and is not to be greater than λ or the greatest height we can with safety give to a wall with vertical faces. That of the lower portion C D E F, may also be conducted on the principles previously laid down, and as it necessitates several eliminations of somewhat startling length we shall consider it merely in outline. Knowing the total height of the dam, and the distance A D, we of course know D G, or the height of that portion of the dam C D E F, whose breadth of base E F, we wish to find. We also know from equations 51 and 54, the breadth D C, and projecting this on the base we at once obtain that portion

of it between G and H. What there remains to be found is G E, and H F. The former of these unknown quantities we will denote by y, and the latter by z; the breadth E F, of the base by b," the part G H, which is also equal to C D, by b'; the height D G, of the lower section of the dam by a, and that of the upper section, or A D, by a'. Returning now to the equations 15 and 16, which are the general equations of stability for a dam supporting the pressure of a head of water, we find that the three unknown quantities for which we wish to find

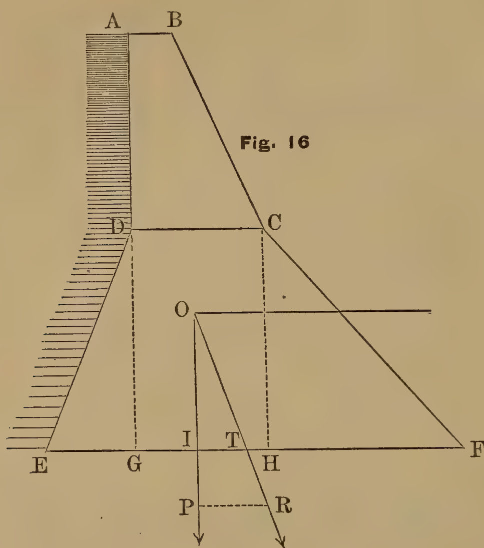


Fig. 16

values in term of known quantities we possess are u, l, and p. The value of l, or the thickness E F, of the base is when expressed in terms of the above notation.

$$l=y+b+z$$

While P is of course the area of the irregular polygon A B C F E D multiplied by the weight per unit of volume, *plus* the *vertical* component of the weight of the water resting on the sloping face D E. The area of A B C D is $\left(\frac{b+b'}{2}\right)\delta' a'$. That of C D E F is $\frac{y a \delta'}{2}+\frac{z a \delta'}{2}+b' \delta' a$. The vertical thrust of the water is by equation (1) $\left(\frac{2a'+a}{2}\right) y\,\delta$. The value of P, therefore, is $b'\delta' a+\frac{y a \delta'}{2}+\frac{z a \delta'}{2}+\left(\frac{b+b'}{2}\right)\delta' a'+\left(\frac{2a'+a}{2}\right) y\,\delta$, which reduces to the form

$$P=\frac{2b'\delta' a+\delta' a(y+z)+2(b+b')\delta' a'+(2a'+a)y\,\delta}{2} \quad 59.$$

Again, to find the value of u, the first step is to construct the diagram of forces, as illustrated in the figure, O P representing in direction and intensity the vertical component P, or the weight of the dam and the water, and O F the horizontal component or the outward thrust of the water behind the dam. Then will F r represent u which is clearly equal to

$$u=z+\text{H I}-\text{I}\,r\,. \quad . \quad . \quad 60.$$

But by the two similar triangles we have, as before, $\text{I}\,r=\text{O I}\times\frac{\text{O F}}{\text{O P}}$ or since $\text{O I}=\frac{a+a'}{3}$ and O F (equation 2) equals $\left(\frac{a+a'}{2}\right)^2\delta$

$$\text{I}\,r=\frac{(a+a')^3\,\delta}{3\,[2b'\delta' a+\delta' a(y+z)+2(b+b')\delta' a'+(2a'+a)\,y\,\delta]}$$

H I is to be obtained in precisely the same manner as K C was obtained from Fig. 14, by expressing the relation that the moment of weight P (which includes, it is to be remembered, that of the dam and

that of the water pressing on the inclined face D E), with respect to the point F is equal to the sum of the moments of the components of this force. Obtaining these moments in the same manner as we obtained those for the equations deduced from Fig. 14, and putting them equal to the expression P × I F, or P × (I H + z), we have after reduction, the equation

$$IH = \frac{12 \propto \beta + b'^2 a + 2\, a\, y^2 + 6 b' a\, y + (b\, a' + 3\, a)(y + 2\, b')\, y\, \theta - 2\, z^2\, a}{(12 \propto + b' a) + 6\, a\, z + 6 a y + 12\, a' y \theta + 6 a y \theta}$$

In which $\propto$ is a short expression for the area of A B C D, and β the distance from C to the point where the perpendicular of the centre of gravity of A B C D cuts C D, and this replaced in equation 60, gives for the value of u

$$u = \frac{12 z(\propto + b' a) + 6\, z\, a(y + z) + 6\, z y \theta (2 a' + a) + 12 \propto \beta + 6\, b^2\, a + 2\, a\, y\, (y + 3\, b') + 3\, (2\, a' + a)\, (y + 2\, b')\, y\, \theta - 2\, a\, z^2 - 2\, \theta\, (a' + a)^3}{12(\propto + b' a) + 6\, a\, z + 6 a y + 12 a' y \theta + 6 a y \theta} \qquad \text{Eq. 61.}$$

The quantities P, u and l, being thus obtained in terms of b', y, z, a and a', a substitution in equations 15 and 16, will furnish us with two equations of great length, from which, by the process of elimination, the values of x and y are readily found.

To take but one example of this form of profile, let it be required to calculate the dimensions of such a profile for a masonry dam one hundred and seventy feet in height and eighteen feet broad on top, the limit of pressure being taken at 132,000 pounds. For this purpose we have to determine beforehand the height a' of the part A B C D. This, in the present case, is taken at 80 feet, and may in all cases be assumed arbitrarily. Now, since the dam has one vertical face, we have to determine but one quantity v, or the difference between the thickness of the dam at A B and that at C D, and this value of v is readily obtained from equation 51, which, modified to suit the present notation, becomes

$$\theta\, a^3 - \lambda\, v^2 - 2\, b\, \lambda\, v + b^2 a' - \lambda\, b^2 = 0 \quad . \; 62.$$

Solving this with reference to v, we have

$$v^2 + 2\, b\, v = \frac{b^2\, a' + \theta\, a'^3}{\lambda} - b^2$$

$$v = \sqrt{\frac{b^2 a' + \theta\, a'^3}{\lambda}} - b \quad . \quad . \quad . \quad 63$$

And replacing the quantities by their values, remembering that λ equals 98.4 ft., and θ (or the ratio in which the masonry is heavier than water) equals $\frac{1}{2}$, the result finally obtained is,

$$v = 53.52 - 18 \text{ or}$$

$$b' = b + v = 53.52 \text{ feet.}$$

With this value of b' we return to the equations expressing the values of x and y as deduced from equations 15 and 16, after the substitution of the value of u given in equation 61, and find that the value of $b'' = x + b' + y$ is 178.42 feet.

Once more, we may carry this principle one step further and produce a profile which is little more than a modification of that given in Fig. 16. If, for instance, while preserving the same height of structure, we divide each of the three sloping faces into two parts, and give to each part thus produced a face inclined to the horizon, we shall then have a profile of such shape as that illustrated in the seventeenth figure.

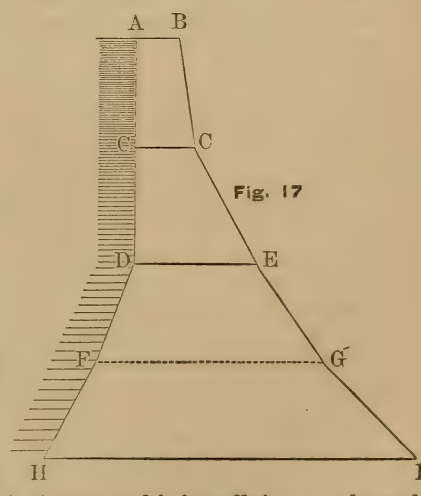


Fig. 17

A glance at this is sufficient to show that it is in reality but a compound of the two preceding profiles, and that therefore the principles to be observed in the calculation of its parts are those already discussed. The entire profile may thus be considered as divided into three pieces ;—that from A to D, in which the

inner face is vertical throughout, and the outer made up of two inclined faces, constituting a profile exactly similar in design to that of Fig. 12: that from D to F, and that from F to H, in each of which both the outer and inner faces are sloping. The first part is, therefore, to be calculated in the same manner as we would calculate the thickness of a dam having the profile of Fig. 12, and each of the two remaining portions by the equations deduced from Fig. 16. To illustrate this by a case in point, let it be required to find the thickness at various points of a masonry dam, having such a profile as that we are discussing, its thickness across the top being 18 feet, and the total height 170 feet. The first thing that claims attention is the determination of the vertical distances between the points B and C; C and E; E and G; and finally G and I. These may, of course, be chosen at pleasure, just as we may select the number of parts that each face is to be composed of, and as in the present case the dam is 170 feet high, and the outer face divided into four parts, we will for convenience divide the dam first into two equal parts, then divide the lower of these again into two equal parts, and the upper also into two, but two unequal parts. The vertical distances between the sections will then be, beginning at the bottom and going up G I = 42.5 feet; E G = 42.5 feet; C E = 45; and B C = 40 feet. Had the dam, however, been one hundred and fifty, or one hundred and eighty feet high, or indeed any other number, then the best arrangement would again have been, to make the second vertical distance—that from C to E—longer than the remaining three, so that, if the dam was one hundred and fifty feet high, the best arrangement would be B C = 30; C E = 60; and E G and G I each thirty feet; if the height had been one hundred and eighty feet, then B C = 40; C E = 50; and the others each forty-five feet. Although this arrangement may seem to be somewhat arbitrary, it is in reality based upon fixed principles, which clearly show that where such a number of divisions and such a profile as that used in the present instance are employed, the second part should be decidedly longer than either of the other three. Those portions, moreover, which are bounded on both sides by sloping faces are in almost all cases made of equal depth, nor does there seem to be any reason whatever for not adhering to this method.

With these distances thus determined, we return to equations 51 and 54, and from the first of these find the value of v, as was done for equation 63, and substituting for a' the value 40, and for b the quantity 18 feet, we have

$$v=\sqrt{\frac{12960+32000}{98.4}}-18=3.37$$

And, consequently, $b'=b+v=21.37$ feet. To find the value of b', however, it is necessary to use equations 51 and 54, from which by the common method of elimination we may find an expression

$$\theta y^3 - v^2 \lambda y - 3 b y v = 0$$

from which by the substitution of the proper values we obtained for a final value of b'', or the thickness of the base of this section, $b''=54.64$ feet, or $v=33.27$ feet. The next step is to find the values of x and y for the third section. As this, and also the last section have both faces sloping, by substituting the value of u given in equation 61, in equations 15 and 16, and reducing and then eliminating, we obtain two expressions for x and y, from which we derive the thickness G F = 100.36, and by a similar process find that for I H to be 152.22 feet.

It is thus apparent, that as there is almost no limit to number of sections into which a dam may, on this principle, be divided, there are a great number of different forms of profile, each of which, satisfy the conditions of stability, but vary somewhat as to economy. Theoretically the dam whose outer face consists of the greatest number of these sloping faces is the most economical, because in that case its face approaches nearest to the logarithmic curve which bounds the theoretical profile of equal resistance, and it therefore contains very little more masonry than is absolutely necessary to insure safety. In practice, however, such a dam would, in all probability prove much more costly than one consisting of a less number of section, though containing more masonry, because the angle of inclination of the different sections of the outer face

changing so frequently would greatly increase the cost of cutting the facing stone. To avoid the mechanical difficulties also likely to arise in such cases, it is sometimes well to depart altogether from this style of profile, and instead of sloping the outer and inner faces, cut them into notches or steps.

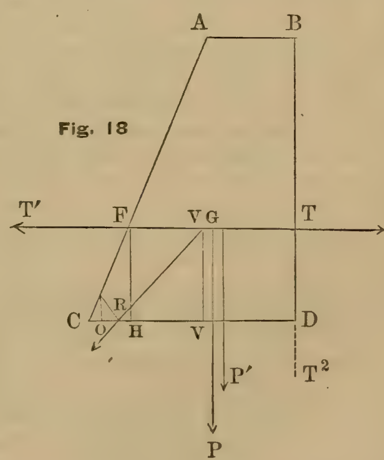
THE STEPPED PROFILE.

The stepped profile has been reserved to the last for consideration, because, while it is a natural outgrowth of the preceding modifications, it possesses many merits whose importance cannot be fully appreciated till a comparison is instituted between it and the forms just treated of. In point of simplicity of construction for instance, it would be difficult to find any design of profile that can surpass it. Wherever the faces of the dam are curved as in Fig. 9, or made up of a series of sloping surfaces of various inclination as in Figs. 12, 16 and 17, the dimensions of every facing stone that is set have to be most carefully determined beforehand by the rules of stereography, and this, when the dam is an high one and the number of stones consequently large, is of itself a work of no small difficulty. In the stepped dam however, all this is done away with, as every facing stone, (unless the dam is curved) possesses only a vertical or, if it happens to form the edge of the step, a vertical and horizontal face, and thus requires no pattern for the stone cutter. A further advantage to be derived from it, is, that it enables us to approach much nearer the curved form of profile than we can in any other profile type. Indeed, when well designed it is in reality nothing but the logarithmic curved profile cut into steps or notches, so that should we draw a continuous line through the upper edges of all the steps, or through the lower edges of their vertical faces, this line would form a logarithmic curve.

Here, as in the calculation of the previous profiles, it is quite allowable to assume arbitrarily either the breadth or height of the step and from this one determine the other. Yet it is by far the best plan to assume the vertical height of the step and calculate the breadth. For, it must be apparent, that by this method of procedure, the quantity we calculate is really the abscissa of the curve, which we lay off at regular intervals perpendicularly to the vertical axis of the dam, and in this way we are enabled to preserve very closely the logarithmic profile. The general appearance of the dam is, moreover, much more pleasing when this arrangement is observed than when we assume a constant breadth and calculate depth, because the breadth of the steps near the summit of dam are then very narrow and increase gradually as they approach the bottom, and the departure from the curve is then scarcely perceptible; but when the breadth is everywhere the same and the depth varies, the whole face of the dam has an extremely broken appearance, which is anything but agreeable.

In this profile, as in all the others, the inner face is made vertical for as great a distance as the limit of pressure will allow, and from that point down it is stepped. The outer face is likewise made vertical for a distance which depends in all cases on the thickness across the top, being as a general thing very nearly twice that dimension. In the determination of the following formulæ, the depth of the step has been assumed as the same throughout the entire dam, and the breadth has been taken as the unknown quantity. Fig. 18 then represents a portion of the profile of a dam bound by a curved or sloping face, which we wish to change into a stepped profile. A B D C represents this section, and if H F be taken as the vertical height of the step, then will C H F represent the

Fig. 18



element with which we are especially concerned, and its base C H the quantity we are in search of,—the breadth of the step. The height B D of the section we will denote by h; and the density of the masonry by δ'; and the greatest thickness F T or H D of the *known* element A B T D H F by t; from which three quantities we may obtain an expression for the weight P, of this element, which must of course be accurately known, inasmuch as the object of making the step at this point being to lessen the amount of vertical pressure on each superficial unit, the breadth of the step will depend very largely on the weight of that portion of the dam which is above it. The weight which is plainly equal to $\left(\frac{AB+FT}{2}\right) BT\,\delta' + (FH \times HD)\,\delta'$ is expressed by P, while that of the element C H F is equal to $\frac{b\,a\,\delta'}{2}$, in which a is the height of the step F H, and b the breadth C H. The point of application of the thrust of the water is T situated at two-thirds the depth of immersion. T′ and T² the horizontal and vertical components respectively. Then will P represent the direction of the resultant of P and T²; V V the resultant of P, T² and the weight $\frac{a\,b\,\delta'}{2}$ of the element C H F, while the general resultant of all the forces is R. Now, in this case, as in the previous ones, the whole solution of the problem depends on finding the value of C R, or the distance from the outer edge C to the point where the resultant cuts the base, and this we will express as heretofore by the letter u. Then from the figure

$$u = CH + HV - RV \quad . \quad . \quad . \quad 64.$$

in which we know the value of $CH = b$, and require that of H V and R V. But $\frac{RV}{VV}$ is equal to the tangent of the angle which the general resultant R makes with the vertical, or calling this angle $\propto$ then

$$\tan.\propto = \frac{RV}{VV} = \frac{T'}{P + \frac{a\,b\,\delta'}{2}},$$

$$RV = \frac{T'}{\frac{P + \frac{a\,b\,\delta'}{2}}{VV}} = \frac{T'\,e}{P + \frac{a\,\delta'\,b}{2}}$$

in which e is to be understood to express the value of $VV = \frac{BD}{DT}$. The distance H V may be found from the theorem of moments, by expressing the relation that

$$HV \times \left(P + \frac{\delta'\,a\,b}{2}\right) = M - \frac{\delta'\,b^2 a}{6}$$

$$HV = \frac{M - \frac{\delta' b^2 a}{6}}{P + \frac{\delta' a\,b}{2}}$$

M denoting the moment of P′ with respect of H. As to C H, its value is b, the quantity we are in search of. Replacing these quantities in the equation expressive of the value of u, we have

$$u = b + \frac{\frac{M - \delta'\,b^2\,a}{6}}{P + \frac{\delta'\,a\,b}{2}} - \frac{T'e}{P + \frac{a\,\delta'\,b}{2}}$$

which, reduced to a common denominator, becomes

$$u = \frac{6\,b\,P + 3\,b^2\,a\,\delta' + M - \delta'\,b^2\,a - 6\,T'e}{6\,P + 3\,\delta'\,b\,a} \quad 65.$$

Having thus obtained an equation for the value of u, the next step is to find by means of it an expression for b the breadth of the step. For this purpose draw from R, the point at which the general resultant of all the acting forces cuts the base, a perpendicular R N to the resultant, and from N a perpendicular to the base C D, thus forming a triangle R N O. Then, since the two triangles R V V and R N O have their bases on the same right line C D, and the side VR of the one perpendicular to the side N R of the other, and the sides V V and N O parallel, the angles at V and N are equal and the triangles are similar. But by the relation existing between the sides of such similar triangles, we have the proportion

$$NO : RV :: RO : VV.$$

which gives for N O the equation

$$\text{N O} = \frac{\text{R V} \times \text{R O}}{\text{V V}} = \frac{\text{T}' f}{\text{P} + \frac{\delta' a b}{2}} \quad . \quad . \quad . \quad 66.$$

where f is the distance R O. But we have another pair of similar triangles which gives yet another value for N O, which must be deduced and made equal to that just found. These triangles are C O N and C H F, and the proportion derived from the relation of their sides is,

$$\text{N O} : \text{C O} :: \text{F H} : \text{H C} \quad \text{or}$$

$$\text{N O} = \frac{\text{C O} \times \text{F H}}{\text{H C}} = \frac{\text{C O} \times a}{b} \quad . \quad 67.$$

Equating equations 66 and 67,

$$\text{C O} \times \frac{a}{b} = f \times \frac{\text{T}'}{\text{P} + \frac{\delta' a b}{2}}$$

$$\text{C O} : f :: \frac{\text{T}'}{\text{P} + \frac{\delta' a b}{2}} : \frac{a}{b}$$

And again, since if four quantities be proportional they will be in proportion by composition and division

$$\text{C O} + f : f :: \frac{a}{b} + \frac{\text{T}'}{\text{P} + \frac{\delta' a b}{2}} : \frac{a}{b}$$

and reducing,

$$f = \frac{u \frac{a}{b}}{\frac{\text{T}'}{\text{P} + \frac{\delta' a b}{2}} \times \frac{a}{b}} = \frac{u a (\delta' a b + 2 \text{P})}{a (\delta' a b + 2 \text{P}) + 2 \text{T}' b} \quad 68.$$

But the condition of stability is (equation 16) expressed by the relation

$$f = \frac{2 \left(\text{P} + \frac{\delta' a b}{2} \right)}{3 \delta' \lambda} \quad \text{or} \quad \frac{2 \text{P} + \delta' b a}{3 \delta' \lambda} \quad 69.$$

And equating these values given in equations 68 and 69,

$$\frac{u a (\delta' a b + 2 \text{P})}{a (\delta' a b + 2 \text{P}) + 2 \text{T}' b} = \frac{2 \text{P} + \delta' b a}{3 \delta' \lambda}$$

Substituting for u its equivalent value as given in equation 65, and dividing both members of the resulting equation by the common factor $2 \text{P} + \delta' b a$, there results

$$\delta' \lambda a (6 b \text{P}' + 3 b^2 \delta' a + 6 \text{M} - 6 \text{T}' e - \delta' b^2 a) = a (2 \text{P}' + \delta' a b + 2 b \text{T}') (2 \text{P}' + \delta' a b)$$

Solving this with respect to $x b^2$, and extracting the root,

$$b = -\frac{\text{P}}{\delta'} \frac{3 \lambda - \frac{2 \text{T}'}{\delta' a} - 2 a}{2 \lambda a - a^2 - \frac{2 \text{T}'}{\delta'}} + \sqrt{\frac{\text{P}^2 \left(3 \lambda - 2 a - \frac{2 \text{T}'}{\delta' a} \right)^2}{\delta'^2 \left(a (2 \lambda - a - \frac{2 \text{T}'}{\delta'} \right)^2} + \frac{\frac{\text{P}^2}{\delta'^2} + 3 \lambda \left(\frac{\text{T}' e}{\delta'} - \frac{\text{M}}{\delta'} \right)}{2 a \lambda - a^2 - \frac{2 \text{T}'}{\delta'}}}$$

But this is capable of being yet further reduced by dividing through by

$$\frac{3 \lambda - \frac{2 \text{T}'}{\delta' a} - 2 a}{2 \lambda - a - \frac{2 \text{T}'}{\delta'}}$$

to the form

$$b = -\frac{\text{P}}{\delta' a} + \sqrt{\frac{\text{P}^2}{\delta'^2 a^2} + \frac{\frac{4 \text{P}^2}{\delta'^2} - \lambda \left(6 \frac{\text{M}}{\delta'} + \theta h^3 \right)}{3 \lambda a - 4 a^2}} \quad 70.$$

which is the expression for the breadth of the step. As to the meaning of the letters it may once more be stated, that P is the weight in pounds of A B D H F, and δ' the density of the masonry. The *vertical* height (F H), which we determine to give the step, is expressed by a, that of the entire dam from the top to the *base* of the step by h, and the *moment* of the weight P, with respect to the vertical F H forming the *rise* of the step by M; while by λ, we mean, as in all previous formulæ, the greatest height to which we can raise a vertical wall without the pressure per unit of surface on the base, becoming larger than the limit R′ of pressure; and by θ, the expression $\frac{\delta}{\delta'}$, or the ratio in which the density of the masonry exceeds that of water. This value of θ, is safely taken at $\frac{1}{2}$. As to the height to be given to the step, this is of course to be assumed at pleasure, but the most pleasing effect is produced when it is taken at six or seven feet, for then, even in dams of one

hundred and sixty feet in height, constructed of the heaviest stone, the breadth of the step will rarely at any point be materially greater than the rise. The point on the outer face at which the first step should begin, or in other words the distance A B, in Fig. 19, is determined, as in the other instances, by the

Fig. 19

relation which the breadth on top bears to the height. If the thickness t, across the summit be assumed then

$$a=\sqrt{\frac{3\,t^2}{\theta}+\frac{4\,t^4}{\theta^2\,\lambda^2}}-\frac{2\,t^2}{\theta\,\lambda}$$

but if the height a be assumed the proper thickness is to be had from the equation,

$$t=a\sqrt{\frac{\theta\,\lambda}{3\,\lambda-4\,a}}$$

When that point on the inner face is reached, at which it becomes necessary to begin stepping, the breadths b and b', of the outer and inner steps respectively, may be had by substituting the value of u, in equations 15 and 16, and from the two resulting equations, finding by elimination two expressions for b and b'. This calculation may, however, be avoided, and considerable expense for cutting facing stone saved, by making the inner face vertical from top to bottom. Indeed the matter of expense for dressing stone is, perhaps, the most serious objection to the stepped profile, as it is necessary to dress both faces of the step.

As regards the use of the formulæ for this form of profile, it is to be borne in mind, that P includes the weight of the water as well as the weight of the masonry, so that in determining the breadth of the fourth step, the weight of the three columns of water resting, one on the first, one on the second and one on the third step, is to be added to the pressure of the masonry. The pressure of the water is readily obtained from equation 1.

The principles that have now been established in connection with the four types of profiles treated of, are all that are required to calculate the parts of any profile that is ever likely to arise in practice. They have, moreover, been determined without regard to the length of the dam, so that the structure will be one of equal resistance, and withstand the thrust of the water solely by its own weight. There is, therefore, no valid reason why a dam constructed with a profile of equal resistance should be curved into the form of an arch, and this holds good, whether it be high or low, whether it obstructs a broad valley or a narrow one. The only thing that

can be accomplished by curving a dam, is to relieve it from severe strains, by transmitting as large a part of the thrust to the sides of the valley, but where the profile is such that the dam is everywhere equally strong, and equally capable of resisting by its own weight the severest strain it is ever subjected to, there is surely nothing to be gained by increasing its length in order to transmit this thrust laterally to the sides of the valley. It is true that in deep and narrow valleys, some saving of material may be affected by curving the dam, which being thus relieved from a goodly portion of the thrust, may be diminished in thickness. But in long dams, it is an open question whether the saving thus affected is not more than balanced by the increased length.

One other matter which deserves the most careful attention, and which indeed unless it is carefully attended to will render the very best profile of no account, it is the binding of the stones, and the character of the inner filling. As to the bond, it is undoubtedly the wisest plan if the dam is to resist a great pressure, to *avoid* laying the stones in horizontal courses wherever such a thing is practicable, and to place *binders* in every possible direction. For assuredly, if it is necessary for the stability of all walls bearing a vertical load, that there should be no continuous joints in the direction of the pressure, it is just as important that a dam should have no *continuous horizontal joints*, because in the case of such structures almost every ounce of thrust they have to resist is horizontal, and thus exactly coincides with the joints. If the dam is *curved*, then this matter of broken horizontal joints is not of such *vital* importance, because no layer can then slide until some one of the stones has been crushed, yet even here it cannot be too rigidly adhered to. By a strange inconsistency on the part of engineers, we often see this matter both regarded and disregarded in the same dam. Many structures of this class could be named, in which the rock foundation is stepped with the utmost care to preclude any possibility of sliding where sliding is of all places the least likely to occur, while the courses from the foundation to the top are laid with the most perfect kind of horizontal joints.

The filling again must not be of too different a character from the facing. Where masonry consists of dressed stone and rubble work, the amount of settling is so different in each case that nothing like a bond can be preserved. The affect of such settling, we constantly see illustrated in the most striking way in canal locks. As is well known these are generally cut stone facings with rubble backing, but the latter settling more than the former become detached from the facings, when the water penetrating between the two kinds of masonry, the cut stone facings fall with the first frost. A good filling is that made of large rough blocks of stone, set at regular intervals apart, (the distance increasing as the top is approached) and the spaces between and over them filled in with beton of the first quality, a method, we believe, lately adopted in the construction of one of the Croton dams in this state. But perhaps a yet better one is to replace the beton by the French mixture known as *beton coignet*. Both of these fillings, however, are good, as when well rammed, they form a close connection with the facing stones, and do away entirely with joints of any kind.

A METHOD OF ANGULAR CROSS-SECTIONING.*

By R. BELL, C. E.

In constructing railroads, canals and other works requiring the moving of earth and rock, it is necessary, for the purpose of computing the quantities of material moved during the process of construction, that the engineer should have an intimate knowledge of the ground on the line of the work. This is obtained by means of cross-levels taken at right angles to the reference line of

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the work at every station, and at such points between stations as the irregularity of the ground may render them necessary. This work in engineering parlance is cross-sectioning. The method herein described is a special application of the system of angular leveling. It can be used to great advantage in obtaining cross-sections of rock cliffs, steep side-hills, and rough irregular ground in general where it may be impossible to follow the ordinary operations with the *Y* level or the level straight-edge, or where the notes taken by those methods are untrustworthy, because of the difficulty of making accurate horizontal and vertical measurements. I have found it extremely useful and economical in obtaining accurate cross sections of rock cliffs with perpendicular faces and overhanging ledges; where accurate sections are rarely obtained by means of the methods in common use, and where there is really the greatest need of them, because of the high prices usually paid for excavating and moving rock.

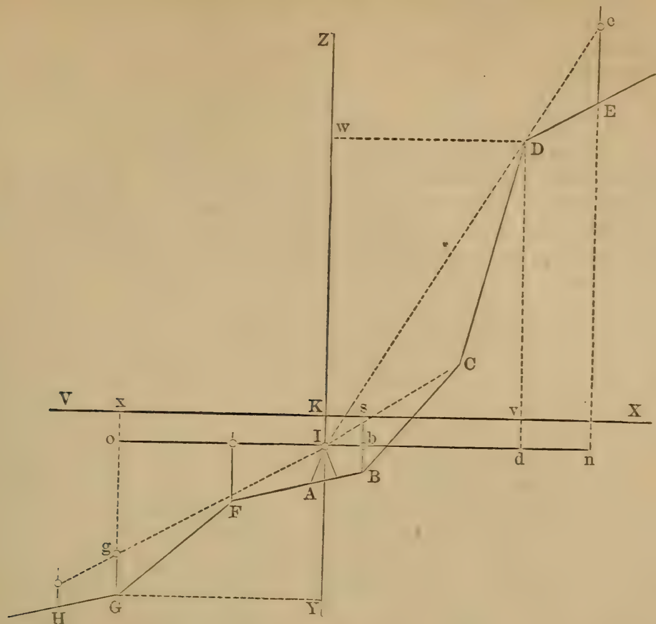
The requirements for the proper carrying on of the field work are as follows: a transitman who directs the work; two rodmen; a transit with level on telescope and vertical circle; a tape, divided into feet and tenths, to measure 100 feet; and a plain rod 14 or 16 feet long. A telescope with level attachment is required so that the transit may be used as a leveling instrument. The vertical circle is needed for the purpose of measuring angles in the vertical plane of the cross-section. One of the rodmen acts as a tapeman, while the other is carrying the rod; and as the rod work is apt to be fatiguing, it is best to have them alternate at it about every second cross-section. When it is necessary to measure distances greater than 100 feet, or the length of the tape, it is best to use a line made of the flat steel wire which is used in the manufacture of hoop-skirts. At one end of the line there should be a ring securely fastened, and at every 10 feet there should be soldered a small piece of thin brass which has stamped on it the distance in feet from the ring end of the line. The plus distances can be measured with the tape. Three hundred feet of such a steel line can be conveniently carried on a light reel, and it will be found very useful for a variety of work.

The best rod is made of straight grain pine, and is about one and one-quarter by two and one-quarter inches in size. The lower end should be protected from wear by a suitable shoe of iron or brass. Have the rod painted white. Divide it longitudinally on one of the wide sides, beginning at the lower end, into feet, tenths, and hundredths, by black lines. The foot lines should extend across the rod, the tenth lines one-half way across, and the hundredth lines one-quarter of the way across. The foot lines should be marked with bright red figures twelve hundredths in height, and the tenth lines by black figures four hundredths in height, the middle of each figure being across the line which it designates. The hundredths can be read from the rod by the observer at the transit. The black marks and figures wear the best when they are burnt into the wood, but paint answers very well if the rod is varnished with hard drying varnish after the paint has become thoroughly dry. The rod should be fitted with a clamping target, which has fastened to its face on the horizontal centre line, and as near to the vertical centre line as it can be placed, a small hook for the purpose of attaching the ring of the tape. The rod should also be provided with a screw or hook projecting from the top, to be used for the same purpose.

These notes are more particularly descriptive of cross-sectioning on railroad work, where the centre line has been located, levels run over it and the grade line established. It is supposed, also, that the cross-sectioning and "staking out" on ordinary ground has been done, or will be done, by the method in common use, and that the angular method is to be used only for the purpose of taking sections on such ground as it is peculiarly adapted for.

Referring to the accompanying sketch, and to the field-book notes which are given below, the description of the manner of working will be readily understood.

A, in the sketch, is the point in the centre line where the cross-section is to be taken. *I* represents the transit. In the description, *I* will be used to indicate the axis of the telescope, to which



all measurements are taken. *H, G, F, B, C, D, E,* are the points in the cross-section which it is desired to note. A line connecting these points represents the surface of the ground. *VX* is the grade line of the section. The line of collimation when the telescope is level, is represented by *o In*. *YZ* is a vertical line through A and *I*.

Column 1 of the field book has entered in it the station *A* of the centre line where the section is taken.

Column 2 contains the "height of instrument;" or, in other words, the elevation of the line of collimation, *o n* above the datum plane, when the telescope is level. The height of instrument is found by carrying the line of levels from the nearest bench-mark to the point where the instrument stands. The level notes may be kept in a compact form on the margin of the right-hand page of the field book, by adding the backsight, or the reading of the rod when it is held on the bench-mark, to the elevation of the bench-mark, then subtracting foresights and adding backsights successively; the sum after adding any backsight will be the height of instrument at that time.

Column 3 has entered in it the "grade," or the elevation of the grade line *VX*, above the datum plane, at the given station. This is taken from a list of grades which has been entered in the back part of the field book, as obtained from the profile of the located centre line.

Column 4 contains the difference between height of instrument and grade at the given station. If height of instrument is *above*, or higher than grade, the difference is marked *plus*; if height of instrument is *below*, or lower than grade, the difference is marked *minus*. This difference is constant for all the points of each cross-section, and it is used in the computations as if written in each line of the field notes.

Column 5 has entered in it the reading of the rod. This is always subtractive, and takes the minus sign.

Column 6 contains the measurement to the right or left from *I*, to the point which is noted, or to some observed point on the rod when it is held vertically upon the required point.

Column 7 contains the angle which the line of collimation makes with the horizontal, when the telescope is sighted at the point to which the measurement noted in column six is taken. It will be observed that for each station there will be as many entries in each of the columns 5, 6 and 7, as there are points noted in the cross-section at that station.

Columns 8, 9, 10 and 11, are not required for the field work entries.

All elevations, measurements, rod readings, and results of computations, are given in feet and decimals. This being understood, the words *feet* and *decimal* may be omitted in the "calling off," and for the same reason the following description will be abbreviated; an elevation such as two hundred and forty six, and forty-four one hundredths feet (246.44), being called off, or read as two, forty-six, forty-four; a rod reading, such as two feet (2.0), is called off, two, naught; and a measurement such as three and three-tenths feet (3.3), is called off as three, three.

FIELD BOOK NOTES.

1	2	3	4	5	6	7	8	9	10	11	Points.
A	246.44	248.84	−2.4	−3.1	*C*	0	−5.5	0	0	−5.5	*A*
				−2.0	*R.* 3.3	0	−4.4	0	*R.* 3.3	−4.4	*B*
				0	*R.* 13.0	+33°16′	−2.4	+7.1	*R.* 10 8	+4.7	*C*
				0	*R.* 30.5	+58°30′	−2.4	+26.0	*R.* 15.9	+23.6	*D*
				−6.6	*R.* 41.8	+58°30′	−9.0	+35.6	*R.* 21.8	+26.6	*E*
				−4.6	*L.* 7.7	0	−7.0	0	*L.* 7.7	−7.0	*F*
				−3.5	*L.* 19.4	−28°52′	−5.9	−9.4	*L.* 17.0	−15.3	*G*
				−2.0	*L.* 25.1	−28°52′	−4.4	−12.1	*L.* 22.0	−16.5	*H*

In order to explain the field work, we will suppose that the transitman—starting from the nearest bench-mark, using his transit as a leveling instrument, and following the ordinary leveling operations—has arrived at a point *A*, where a cross-section is desired, and has set his transit over a stake or peg in the centre line at that point. A sight is then taken on the centre line, and 90° are turned off, which insures the cross-section being taken at right angles with the centre line. The transitman now enters station *A* in column 1 of his field book. The height of instrument has been found to be 246.44, which is entered in column 2. Grade in column 3 is 248.84. Height of instrument is *below* grade, and the difference is entered in column 4 as —2.4. The distance from *I* to the level of the ground at *A* is found to be 3.1, which is entered in column 5 as if read from the rod through the telescope, and being a rod reading or its equivalent, it takes the minus sign. *C* in column 6 indicates that the point which is noted is in the centre line. Since there is no angle, zero is entered in column 7. The telescope is now clamped level, and a sight is taken on the rod as it is held on the point *B*. The reading *B b* is 2.0 and is entered in column 5. The tapeman, standing at the right of the transitman, calls off the distance *b I* as right 3.3, which is entered in column 6, *R* being substituted for the word right. Since the line of collimation is horizontal, there is no angle, and zero is again entered in column 7. The end of the tape is now hooked on to the screw, or hook, in the top of the rod, and the rodman pushes it up the slope to the point *C*. After indicating that the end of the rod is at the point which he desires to note, and that it is to be held there, the transitman sights at it, or at the point, and clamps the telescope. At the same time the tapeman ascertains the distance *C I* to be *R.* 13.0, and it is so entered in column 6. The sight having been taken directly at the point, there is no rod reading, and the entry in column 5 is zero. The angle of *I C* with the horizontal *In* is found to be 33° 16′, and it is entered in column 7 as + 33° 16′, the *plus* sign being placed before it because the angle is taken *above* the horizontal.

The next in order is the point *D*, which the rodman reaches either by climbing, by going around the end of the cliff, or by means of a ladder. The end of the tape being held at the point, a sight is taken to it, and the telescope being clamped as before, the angle is found to be + 58° 30′. The rod reading is zero, and the distance *D I* is 30.5 If the sight clears the edge of the cliff, the

telescope is allowed to remain clamped, and the transitman directs the rodman to go back from the face of the cliff to a point E, as far as he expects the excavation to extend. The rod is held in a vertical position on the point, while the transitman signals the target to be set and clamped; which being done, the reading Ee is given as 6.6. The rodman then holds the end of the tape at the centre of the target, while the tapeman ascertains the distance $e\,I$ to be 41.8. These entries are made in the proper columns; the angle in column 7 being the same as that for point D.

If the point E should be so far back that the rodman cannot reach to set the target, he holds the rod in a vertical position until the transitman takes a sight on it and calls off the reading at which the target must be set. This the transitman can easily do, as there is no difficulty experienced in reading a rod, such as the one described, at a distance of 300 feet. Having the required point on the rod given him, the rodman clamps the target at it, and attaches the end of the tape to the hook on the face, then the rod being again raised to its vertical position, on the point E, and the transitman having signaled all right, the reading and distance are obtained as in the first case.

As all the points which are needed on the right of the centre line have now been noted, the transit is reversed and the points on the left are taken. The notes of the point F are taken and entered, similar to the notes of point B. L, for left, being placed before the distance in column 6, instead of R. The notes of the points G and H are taken and entered in a manner similar to the notes of the point E; with these exceptions, however, that L is substituted for R in column 6, and the *minus* sign is given to the angles in column 7. The last being for the reason that the angles are taken *below* the horizontal.

A diagram of the cross-section can be made directly from the notes thus recorded, by using a protractor and scale. But the process is slow, and the diagram is inconvenient since it involves the use of a scale whenever it is necessary to refer to it.

Cross-sections of railroad work are always plotted with reference to the grade line of the section as a base, and usually on the regulation cross-section paper. That is, paper ruled with two sets of lines at right angles with each other, every tenth line being heavier than the rest. The lines being ruled an equal distance apart, the use of a scale for the purpose of plotting the diagrams is unnecessary.

It is desirable for several reasons that the diagrams of the angular cross-sections should conform, as to method of plotting and style, with the ordinary cross-sections. A new set of notes should, therefore, be deduced from the field notes, by means of which the cross sections may be plotted on cross-section paper in the usual manner. In order to obtain such a new set of notes, it will be necessary to substitute for the polar coordinates of the field notes, a system of rectilineal coordinates, the coordinate axes of which shall be a horizontal line corresponding to the grade line of the section, and a vertical line through the point of intersection of the plane of the section and the centre line. Referring to the sketch, the horizontal coordinate axis will be the grade line VX, and the vertical axis will be the line YZ passing through A. If the base line $o\,n$, of the system of polar coordinates was coincident with the grade line VX, the substitution would be very easy, since the vertical coordinate axis YZ passes through the pole I of the system of polar coordinates; and for a point such as E it would be necessary only to find the latitude In and the departure $n\,e$ for the distance 41.8 in column 6 and the angle 58° 30′ in column 7; and then diminish the calculated departure by a distance equal to Ee, the rod reading which has been entered in column 5. But the line $o\,n$ is not coincident with VX, therefore it is necessary to further diminish the calculated departure by a distance equal to IK, which is equal to the difference between height of instrument and grade, already entered in column 4. As VX and $o\,n$ are never coincident, except by accident, it may be safely said that the correction of the calculated departure for the difference between height of instrument and grade will always have to be made. And as the correction for rod reading will also require to be made in a majority of cases,

the work will be simplified if these two corrective quantities are combined before the correction of the calculated departure is made. This is effected by finding and noting the *algebraic* sum of the quantities in columns 4 and 5 for each point of the cross-section. Since the vertical coordinate axis passes through *I*, and the sight and measurement are taken directly to the required point, or to a point vertically over it, the calculated latitude does not need any correction.

The general method by which the system of rectilineal coordinates may be substituted for the system of polar coordinates being understood, the manner in which the work is recorded will now be observed.

Column 8 contains the algebraic sums of the quantities in columns 4 and 5 for each point.

Column 9 contains a departure calculated from the measurement in column 6 and the angle in column 7 for each point. Each departure takes the same sign as the angle which is used in calculating it, and is governed by the sign in the same manner.

Column 10 contains a latitude calculated from the distance in column 6 and the angle in column 7 for each point. Each latitude is governed by the same letter, *R* or *L*, that governs the measurement in column 6 which is used in calculating it.

Column 11 contains the *corrected* departure for each point, *i. e.*, the algebraic sum of the quantities in columns 8 and 9.

The column of points is introduced here for the purpose of showing at a glance which point of the cross-section each line of the notes has reference to.

It will be observed that the signs plus and minus, in addition to being used in the algebraic sense, are also used to indicate that a distance or angle is taken above or below some given line or plane. In column 4 the minus sign shows that the distance is taken below grade. In column 5 the minus sign indicates that the distance is taken below the line of sight. In column 7 the plus line shows that an angle has been taken above the horizontal *o n*, and the minus sign, that the angle has been taken below the horizontal. In column 9 the plus sign indicates that the distance is to be taken above the line *o n*, and the minus sign that it is to be taken below *o n*.

The quantities in columns 10 and 11 comprise the new system of rectilineal coordinates. The letters *R* or *L* before the horizontal coordinates in column 10 indicate in which direction—right or left—from the centre line *Y Z* the distances are to be plotted. The vertical coordinates in column 11 are governed by the signs plus and minus in the manner mentioned above, which is also in accordance with general usage. The plus sign indicating that the distance is to be plotted above the grade line *V X*, and the minus sign, that the distance is to be plotted below the line *V X*.

The computations for a few points will now be given as examples. Whenever the "sum" of any quantities is referred to, the *algebraic sum* must be understood. For the point *A*, the sum in column 8, of the quantities in columns 4 and 5, is —5.5. As there is no distance in column 6, nor angle in column 7, there is neither latitude nor departure to calculate, and the entry in each of the columns 9 and 10 is zero. The sum of the quantities in columns 8 and 9 is entered as —5.5 in column 11. This is correct, as —5.5 is the sum of *A I* and *I K*. For the point *B*, the sum in column 8 of the quantities in columns 4 and 5, is —4.4. The distance *R*. 3.3 in column 6 and zero in column 7, show that the measurement was horizontal. Therefore *R*. 3.3, equal to *I b* or *K s*, is the correct latitude, and it is so entered in column 10. Since there is no angle in column 7, there is no departure to calculate for column 9, and the sum in column 11 of the quantities in columns 8 and 9 is —4.4. This is correct, as –4.4 is the sum of *bs* equal to *IK*, and *B b*. For the point *D*, the sum in column 8 of the quantities in columns 4 and 5 is —2.4, equal to *d v* or *I K*, since there is no rod reading in column 5. Referring to a traverse table, the latitude, for a distance equal to 1, corresponding to the angle 58°30′ is found to be .5225, which being multiplied by 30.5, the distance in column 6, gives 15.9, equal to *I d*, *K v* or *w D*, as the latitude. This, being governed by the same letter as the measurement in column 6, is entered in column 10 as *R*. 15.9. The departure, taken from the table, for the

same angle, is .8526 which being multiplied by 30.5 gives 26.0, equal to $I w$ or $d D$, as the calculated departure. This, taking the same sign as the angle, is entered in column 9 as + 26.0. The sum of the quantities in columns 8 and 9 is entered in column 11 as +23.6, which is correct, as it is equal to the difference between $D d$ and $d v$. For the point G, the sum in column 8 of the quantities in columns 4 and 5 is —5.9, the sum of $o x$ equal to $I K$ and $G g$. The calculated departure in column 9 is — 9.4, equal to $o g$. The latitude in column 10 is L 17.0, equal to $I o$, $K x$ or $Y G$. The corrected departure in column 11 is —15.3, equal to the sum $o x$, $o g$ and $G g$.

It will he observed that the point A is recorded by means of a rod reading alone; the point B by a measurement and rod reading, without any angle; the point D by a measurement and angle, without any rod reading; and the point G by means of all three, angle, measurement and rod reading.

In plotting the cross-section diagrams, columns 10 and 11 of the notes are alone referred to. After fixing upon a horizontal line of the cross-section paper to represent the grade line $V X$, and a vertical line to represent the centre line through A, the plotting is quickly and easily done. To plot the point A for instance.—Zero in column 10 shows that the point has no latitude; therefore a measurement—from column 11—of 5.5 below the grade line and in the centre line, fixes the point. The measurements, of 3.3 to the right of the centre line, and 4.4 below the grade line fix the point B. Two measurements, 10.8 to the right of the centre line and 4.7 above the grade line, fix the point C. In a similar manner all the points are plotted, due regard being had for the significance of the letters in column 10, and the plus and minus signs in column 11.

Slope lines, showing the boundaries of excavations and embankments, can be drawn on the diagrams. The distances from the centre line to the points where the slope lines intersect the ground line, together with the distances of those points above or below grade, should be noted in the field book. Then, when the distances obtained from the diagram are measured out from the centre line on the ground, the slope stakes, with the "cuts" and "fills" marked on them, can be driven in their proper places. A "cut" will be the distance of the point above grade. A "fill" will be the distance of the point below grade. If, during the progress of the cross-sectioning, it is thought that a slope stake is likely to be required in the vicinity of a point, such as E, at the top or foot of a steep slope or cliff, it will be best, in order to obviate the necessity for a further measurement over the difficult ground, to fix the point E when it is noted in the cross-section, by driving a marked stake. The fact that such a stake is driven at that point should be noted in the field book. Then, when the proper location of the slope stake has been found on the diagram, it can be referred to the point E instead of to the centre line. In the case of a rock-cut or quarry, where it is usually impossible to excavate to an exact given line, the finished work can be cross-sectioned and plotted in the same manner as the original ground.

If it should be necessary to cross-section ground which cannot be seen from the transit when it is set in the centre line, as, for instance, ground back of E, a stout peg must be solidly driven at or near E, in the line of the section, and its elevation must be carefully obtained and recorded the same as other points of the cross-section. A stake should also be driven near G or H, so that a pole may be set there for a back sight, in case A cannot be seen from the peg. Since the elevation of the peg and its distance from the centre line can be obtained, the cross-sectioning can be continued by any method, as far back as may be necessary, the peg being used as a "change point" and point of reference for measurements. If the angular method is to be used, the peg must be driven where the transit can be set over it conveniently. Before continuing the cross-sectioning it is well to set the transit up temporarily a short distance from the change peg, and drive a second peg at the same elevation as the first and ten or twelve feet from it. Then, when the transit is set over the change peg, a rod reading on the second peg will give the exact distance from the change peg to the line of collimation. This is, of course, much more, accurate

than a tape measurement from the peg to the axis of the telescope.

If the located centre line is in a pond or stream, or any place where the transit cannot be set, an auxiliary base line may be established at a noted distance on one side, from which the cross-sections can be taken. Before the diagrams are plotted, the calculated latitudes for each cross-section must be increased or diminished by the distance from the auxiliary base line to the located centre line at that cross-section.

The rodman should carry a plummet and line for the purpose of plumbing his rod when the sight is taken at a high point upon it.

If the centre line is curved where the cross-sections are to be taken, the transitman should have the notes of the curve in his field book, so that he may be able to set plus stakes correctly, and also take the cross-sections normal to the curve. Just here the transit is very useful, as the work can be done accurately, while when cross-sectioning on a curve with the level, the setting of plus stakes and laying off of normals is a matter of some judgment and considerable guessing.

The instrumental work of the transitman is comparatively easy, so that he is able to give his attention to the proper directing of his assistants.

Having given a place to set the transit within the line of the cross-section, I think it is safe to say that the only limit to the use of the "angular method" will be the inability of the rodman to reach with the end of the rod or the tape, the point which it is desired to note. And, a rope and ladder and one or two extra assistants being provided, there are very few points that cannot be reached.

As I have not been able to profit by the experience of others in the use of this method of cross-sectioning, I do not claim that the manner of conducting the field work and recording the notes, is not capable of being improved. Indeed, I am inclined to think that at least a slight change in the arrangement of the field notes would result from my further experience.

Whilst writing these few pages I have had in view the fact that they are intended for the perusal of those who have, as yet, had but little experience in the *practice* of engineering, and for that reason I have endeavored to make as plain as possible every point of the field work and computations that might be obscure. In doing so there have undoubtedly been many needless repetitions, and many things have been mentioned which I should not have thought of touching upon if I had not kept in mind the fact—learned through many troublesome experiences—that there are many little technical points and obscurities of engineering practice which, in the nature of things, cannot be brought to the notice of students, things which become so nearly second nature to old engineers that they are not considered worthy of mention, so that the young engineer has to pick them up as best he may. This is my excuse for being apparently so prolix in the treatment of a subject so simple.

Crinoline for Ironclads.—Not because of the sex attributed to armored in common with all other ships, but for the same reason for which, according to the learned Knickerbocker, the maidens of Manhattan enveloped their ample figures in manifold plackets, is it proposed to encircle our ironclads with a network of iron wire, supported by booms at a distance of 22 feet, and kept rigid to below the depth of the keel by heavy weights. The danger to be guarded against is the fish-torpedo, one species of which can be unerringly propelled under water a distance of a mile, and if it then strikes the ship beneath her water-line she must inevitably sink; for it is understood that all the pumps on board a turret-ship, working at their highest pressure, would be incapable of discharging the water which would be admitted through a hole no larger than that made in the *Vanguard* by the prow of the *Iron Duke.* An experiment with this netting is about to be made on the *Thunderer*—the most costly of all ironclads—and there is just a chance that, notwithstanding the crinoline, she may be sent to join what is called our submarine fleet. The Whitehead torpedo appears to be a most effective implement of destruction; indeed, it would seem that there is no end to the "perils that environ" ironclads.

—*Iron.*

THE MARINE COMPASS—CONSIDERATIONS RELATIVE TO CERTAIN FUNDAMENTAL REQUIREMENTS OF IT, WITH SPECIAL REFERENCE TO THE CONSTRUCTION OF THE NAVY COMPASS.

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II.

I have entered somewhat more into dynamical details, especially in regard of these resistances to the motion of a compass-card, than might at first sight seem to be necessary; but, in order to form an intelligent judgment of the conditions which should control the construction of the marine compass, we must take into consideration the laws of the resistances to the card motion, and these cannot be duly appreciated without, at least, a definite recognition of all the elements of these resistances.

Now, with regard to the relation of these resistances to the sensibility of a compass, it will be evident, I think, that the resistance of the medium, however great it may be during certain stages of the motion of the card, cannot give rise to any part of the defect of sensibility; for, in the first place, in regarding this resistance as solely a direct function of the velocity, it must decrease with the velocity and completely vanish with the cessation of motion; secondly, and with still stronger reason, it should follow from the assumption that the resistance varies directly as the square of the velocity; that, as the velocity of the body diminishes in approaching its final position of rest, the resistance of the medium diminishes in the much more rapid ratio of the velocity squared; so that, with the last element of the velocity, the last element of this resistance is a quantity infinitely smaller in comparison.

Hence, it must be concluded that the resistance of the medium, whether air or liquid, has no influence whatever on the ultimate angle of set by which a compass-card deviates from a previous position of rest after being deflected from it.

It is otherwise with the friction at the pivot; for this being a constant force wholly independent of the velocity, it remains the same, during the smaller elements of the velocity, as during the most rapid motions, until it finally comes into equilibrium with the motive forces, and there results an angle of set, or defect of sensibility, which is represented by *the moment of friction divided by the product of the magnet-power and directive force.*

There may be a question whether, in addition to the friction of the cap upon the pivot, there may not be a certain amount of friction due to the action of the fluid in the cap immediately surrounding the pivot. This point is involved in some obscurity at present. It is not easy to separate a possible frictional resistance like this from what is recognized as the resistance of the medium proper; so that it is quite probable, whenever the former has an appreciable value, that it should be merged in the latter, in the results of experiments.

Consequently, the conditions most favorable to the sensibility of a compass appear to be these:

1. That the pressure of the card upon the pivot and the area of the surface in actual contact between the cap and pivot shall both be as small as possible.
2. That the material of the cap and pivot shall be as hard, as true to form, and as smoothly polished as possible; and,
3. That the magnet-power of the card shall be as great and as permanent as possible.

The pressure upon the pivot remains unchanged for the same compass-card; but both the mean radius of the rubbing surface and the co-efficient of friction are liable to increase—the first from the wear of the material and the second from the irregularities and roughness of the wear. The magnet-power is liable to decrease—in some cases very seriously

from original defects in the formation of the card-magnets, and in others from accidental causes incident to the handling of the compass on board ship.

But whatever the angle may be which represents the defect of sensibility, either at the outset or as the result of subsequent changes in the compass-condition, it is always *an error of the compass.* Moreover, it must be regarded as one of the most dangerous errors to which the compass is liable ; because, whenever the actual condition of the compass is unknown, its value is as uncertain as that of the function upon which it depends ; and this may vary from an extremely small quantity, when the *sensibility is practically perfect*, to a quantity as large as unity, when the *sensibility is nothing.*

In passing from the present topic, a remark may be permitted on the preceding definition of sensibility. It will hardly escape notice that the definition here given is not strictly in accord with a prevalent habit of verbal expression, not only among nautical men, but in ordinary popular language. Thus, a compass is said to possess sensibility when "it is lively," when "it moves quickly," etc., without regard, so far as I am aware, to the condition which I have regarded as essential to the idia of compass-sensibility.

Now, a compass-card, when nicely balanced at a jeweled cap upon the point of a hardened pivot, is extremely susceptible to motive influences from purely mechanical causes, independently of any magnet-power whatsoever in the card. The slightest disturbance actually applied to it may be sufficient to set it in motion. It is true that the motion will be different in certain respects when the card at the same time possesses any magnet-power. But the mere excitability of a compass-card, however great, and whether resulting in vibratory or other motions, cannot be regarded as a true or sufficient criterion of its sensibility from a magnetic point of view.

The intrinsic property of a compass-card, alike with that of a simple magnetic needle, is its tendency to return to its position of magnetic equilibrium whenever deflected from that position ; and this is realized under the combined influence of the exterior directive force and its own magnet-power. If it fail in any degree to do this, its most characteristic, not to say its most useful, property is so far imperfect. The question, as it seems to me, is not whether the card is more or less excitable in its movements about its position of rest—for this may depend on several distinct circumstances—but solely whether, in whatever way done, it accomplishes unerringly, and with a nicety of precision that admits of no doubt, its prime function. When it does this—which it never can do except by accident, unless the resistances to motion are so small in comparison to the motive forces as to be uninfluential—then I think that the specific term *sensibility* is both significant and appropriate as the expression of such a fact.

III.—STEADINESS OF THE COMPASS.

A compass-card is said to be stable, or *steady*, when it maintains its position of equilibrium, under the magnetic forces which act upon it, without sensible disturbance by the various mechanical influences which are liable to be called into action on board ship. A compass may possess sufficient magnet-power and perfect sensibility, and yet be so deficient in steadiness, during the rolling, pitching, yawing of the ship, as to be practically useless. But any apparent compatibility of deficient steadiness with perfect sensibility can only exist for a very brief period ; for the effect of much motion of the card must be to blunt or otherwise injure the pivot, or to wear the cap, with the inevitable consequence of increasing the friction, and thereby diminishing the sensibility.

Card-unsteadiness is a mechanical difficulty, and the remedy must be mechanical, so far as it is practicable to have one without compromising the sensibility.

There are two conditions of steadiness, which, at the outset, are always applicable to the cards alike of dry and liquid compasses. These are :

First, that the card shall have a tendency, whenever tilted to one side, to return to its position of horizontal equilibrium. This condition is satisfied by placing the centre of suspension well above the centre of gravity of the card, and also, in the case of the liquid compass, above the centre of buoyancy in the card.

Secondly, that the card shall have no tendency to rock in one direction more than in another; that is to say, no tendency to *wabble* about any of its diameters. And this condition requires that the material of the card shall be so distributed as to give equal moments of inertia about all its diameters. It is satisfied by arranging the relatively heavy card-magnets in one or more symmetrical pairs, on equal parallel chords of the card, at certain calculated distances from the centre.

But these conditions, although on the side of stability, so far as they go, and quite essential to a well-made compass-card of any kind, fall far short in practice of realizing even tolerable steadiness in the air or dry compass; for, while the card may not be liable to wabble, it is still prone to rock in every direction, and, although prevented from actually tilting over, it is liable to spin entirely round in its own plane under the influence of sharp jars or shocks.

Various remedies have been proposed at different times for this serious defect of the air compass. One of these consisted in fixing several projecting pins upon the upper surface of the card, which, by their friction against the glass cover above, might subdue excessive whirling and rocking motions, although no actual contact need exist while the card was in its more quiet and normal condition.

Another compass, well known and still in use, of a celebrated maker, has the provision of a very heavy card, weighing not much less than ten ounces, supported on a fixed spindle passing through it, with upper and lower bearings; and this arrangement, whenever its resistance to motion proves insufficient, is aided by a *friction-brake*, which may be turned on *ad libitum*, until the card becomes quite steady, as it undoubtedly should with the means at command.

The simplest and probably the best provision of this kind is that of a merely heavy card, with enlarged bearing surfaces at the pivot.

These, however, are not a tithe of the different devices which have been resorted to from time to time, as remedies for the evils of an unsteady compass. I have referred to them merely as illustrations of a kind of relief much resorted to even by intelligent navigators of the present day; and yet they certainly appear no more rational than the recourse of the less-informed skipper, whose little craft, dancing like a cockle-shell upon the waves, infects his compass with an excitement which he endeavors to allay by putting brick-dust in its cap. In principle they are the same. The remedy, so far as it proves effective, consists in the production of a moment of friction capable of counteracting the mechanical excitements to motion.

Without entering into any descriptive details, I think it may be said that the prevailing idea of these provisions is that of a heavier card, with more powerful magnets and the use of more rounded pivots. But, with the increase of pressure and bearing-surface at the pivot, there comes a proportional increase in the moment of friction; and thus, while the magnet-power is increased in a certain ratio, the moment of friction is augmented in a much higher one; so that, on the whole, there results at the outset a considerable sacrifice of sensibility, attended by a corresponding error of the compass. And this is not all, for these heavier weights develop proportionally greater wear at the pivot; and, if to this be added the possible deterioration of the magnets, it is not difficult to see that, even if the defective sensibility be tolerated at the beginning, the error from this source is liable to become so great, and withal so uncertain, as to make the advantage gained in mere steadiness (never, I believe, very satisfactory at the best) of doubtful value, in view of the possibly very serious sacrifice in precision.

If practicable, therefore, such a remedy should be found for unsteadiness of the compass-card as shall not impair its sensibility. And this we have by combining with the two preceding conditions a third, namely, *that of placing the compass-card in a liquid instead of a gaseous resisting medium.*

By the use of a liquid rather than an air medium, we gain the advantage of the greatly increased resistance due to the superior density of the former, which, for the liquid likely to be employed, would not be much less than 800 times that of the air. The law of the resistance would be the same in both.

With this provision, the more violent the impulse to motion, the more energetic the resistance ; since, as the velocity of the card increases, the resistance of the medium increases in the more rapid ratio of the velocity squared, while, as already noticed, the resistance decreases in the same rapid ratio as the velocity becomes less.

This is illustrated by a glance at the two horizontal rows of figures, of which those in the upper row represent velocities, and those in the lower row the corresponding proportional resistances :

Velocities,
$32, \ 16, \ 8, \ 4, 2, 1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}, \frac{1}{1024}$

Resistances,
$1024, 256, 64, 16, 4, 1, \frac{1}{4}, \frac{1}{16}, \frac{1}{64}, \frac{1}{256}, \frac{1}{1024}$

Thus, a velocity represented by 32 encounters more than 1,000 times the resistance that a velocity of 1 encounters ; while a velocity diminished to $\frac{1}{32}$ encounters a resistance of less than $\frac{1}{1000}$ of that due to a velocity represented by 1.

Hence the admirable facility with which a liquid compass may adapt itself to such opposite requirements ; in one case presenting the most effective resistance for the destruction of all actual motions of the card, however great ; in the other, offering the least possible obstacle to such motions, when in small arcs about the position of rest, whether in their incipient or terminal stages.

Nevertheless, the advantages even of a liquid medium are greatly enhanced by a certain auxiliary provision, of sufficient importance to be regarded as a fourth condition of steadiness, to wit, *that of the use of a buoyant skeleton-card with a minimum pressure at the pivot.*

With this provision, the resistance to circular motions is greatly increased, not only from the larger effective section of the card, but also from the larger coefficient due to its skeleton form ; and, at the same time, the evil effects of the severe vertical shocks upon the pivot, experienced by the heavy disk-like cards, are greatly mitigated, in a higher proportion even than the reduction of pressure at the pivot.

Of course, the well-known advantage of the gimbal action is not to be overlooked as a fundamental condition of steadiness. But this provision is a condition of all marine compasses, besides entirely outside of the compass-bowl. Without this, or its equivalent, no other provision of compass-steadiness would be of any avail whatever, and even the existence of such an instrument as the marine compass impracticable.

I have thus presented an outline at least of the considerations which, in my judgment, should control the construction of the marine compass, upon the basis of the three fundamental properties assumed at the outset to be essential to its most perfect action on board ship.

IV.—THE NAVY COMPASS IN THE LIGHT OF THE PRECEDING REQUIREMENTS.

The Navy compass, as already intimated, has the distinctive peculiarities of a buoyant card in a liquid resisting medium ; the mean density of the card being so adjusted to the density of the liquid as to produce a small *downward* pressure upon the pivot in the ordinary forms of ship and boat compasses, or a small *upward* pressure against the pivot in the special form of "tell-tale" or cabin compass. The compass-bowl is provided with a self-adjusting expansion-chamber, by means of which the bowl is kept constantly full, without the show of air-bubbles on the one hand or the development of undue pressure on the other, from changes of temperature.

The ship compass of general use has a $7\frac{1}{2}$ inch skeleton-card, with provision for one symmetrical pair of magnets, a division on the outer ring to quarter-points, and a card-circle adjusted to the ring, which is divided to half-degrees. The bowl-circle, or outer edge of the rim upon the bowl, is made rigid and turned strictly to gauge, so as to admit of the interchange, from one bowl to another, of every azimuth circle of its class. The compass is alike used in the steering binnacle or for azimuth purposes.

I shall now briefly consider, under the three general heads previously treated, how nearly this compass appears to be capable of satisfying the conditions therein set forth.

First, with respect to magnet-power.—The magnet-system of this compass consists of two equal compound magnets, inclosed in parallel tubes in the two chords of the circle, a little within the angle of 30 degrees from the parallel diameter. Each magnet is built up of 6

laminæ; each lamina being $6\frac{1}{2}$ inches long, $\frac{7}{16}$ of an inch wide, and about $\frac{1}{40}$ of an inch thick. Each compound magnet weighs about 880 grains, or a little less than two ounces, with but slight variations.

The steel of which these magnets are made is that known in commerce as "Stubb's Sheet," which, from numerous experiments by Mr. E. S. Ritchie, has proved to be the best for this purpose, not only for its uniform excellence, but for its magnetic capacity in both intensity and permanence. In this Mr. Ritchie has but confirmed the conclusions of Doctor Scoresby, of thirty or more years ago, as to the superior qualities of this (English) steel for magnetic purposes.

The laminæ, having been cut to the proper size, are hardened and tempered throughout their entire length, the process being so conducted as to secure a remarkable degree of uniformity in the results. The magnetization is then effected by means of a very powerful electro-magnet to their utmost capacity. After this, the laminæ are separately tested for their relative magnet-power by a deflection-needle, and the angle of deflection marked on each; and, finally, they are laid aside for a little time in promiscuous contact. As required in the formation of card-magnets, these laminæ are next subjected to a careful scrutiny, being taken, one by one, and again tested for magnet-power; and every piece which shows any sensible falling off, as compared with the previous test, is thrown out.

Although I was hardly satisfied, a year ago, with certain details in the formation of our card-magnets, I am convinced that the present process, as just described, is substantially in accord with our best knowledge on this subject, and is destined to leave little to be desired in point of completeness and thoroughness for the end to be attained, namely, *to secure the most powerful magnets, compatibly with the condition of the greatest permanency, for given weights of scale.*

As to the actual magnet-power of the Navy compass, it was important to know how it compared with that of other well-known compasses. For the purpose of a comparison, I selected two $7\frac{1}{2}$-inch cards of well known English makers, the best of their kind, and designed especially for steadiness, as "heavy-cards." One is designated as card "B, 468," the other as card "D, 305," the latter being a spindle card for double bearings. The former has two magnets, and the latter four, in symmetric pairs. Both cards belong to compasses of the collected specimens in my rooms at the Bureau of Navigation, and both appear to be in good condition; but whether either has suffered any loss in magnet-power, as compared with its original condition, I am of course unable to determine.* The Navy card is one of the recent make.

The results of these comparisons, by each of the three methods for finding the magnet-power, are given below:

COMPARATIVE MAGNET-POWER OF THREE COMPASS-CARDS.

I.—*By the method of deflections.*

Designation of compass.	Relative weights of cards.	Distances between centres.	Angle of deflection.	Relative magnet-power.	
				In units employed.	That of N. C. = 1.
	Ounces.	Inches.	Degrees.		
N. C.	$8\frac{1}{2}$	28.8	7.4	3102.4	1.000
B, 468	$3\frac{1}{2}$	26.8	4.5	1514.6	0.488
D, 305	$9\frac{3}{4}$	30.3	9.2	4504.0	1.453

The observations were taken at equal distances east and west of the needle, and the angle is the mean of the two observations. The needle was three inches long.

* These two cards have always been kept on their pivots, in free suspension, taking their respective positions of equilibrium, in a condition to gain rather than lose in magnet-power. The Navy compass-card has, on the contrary, been kept on a shelf, but with its pole toward the north.

II.—*By the method of oscillations.*

Designation of compass.	Time of oscillation.		Relative moment of inertion.		Relative magnet-power.	
	Of card solely.	With the additional weight.	In units employed.	That of N. C. = 1.	In units employed.	That of N. C. = 1.
	Seconds.	Seconds.				
N. C.	11.69	12.94	4.441	1.000	0.0325	1.000
B, 468...............	10.31	12.96	1.725	0.388	0.0162	0.500
D, 305	9.79	10.82	4.520	1.018	0.0471	1.449

The respective times are means of 10 to 16 oscillations; suspension by threads without twist; in small arcs; protected from currents of air.

III.—*By the method of torsions.*

Designation of compass.	Tensions.	Angle of deflection.	Readings of torsion-circle.	Differences of readings.	Angle of torsion.	Relative magnet-power.	
						Mean torsion.	That of N. C. = 1.
	Ounces.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
		0	328				
N. C....	12.5	90 W.	122	154	64	62.5	1.000
		90 E.	177	151	61		
		0	108				
B, 468.........	11.5	90 W.	224	116	26	27.5	0.440
		90 E.	349	119	29		
		0	291 5				
D, 305.........	12.0	90 W.	113.0	181.5	91.5	90.5	1.448
		90 E.	112.0	179.5	80 5		

The tensions for this method were reduced to a condition of approximate equality by the application of weights.

The results by the three methods are in quite close accord, with the exception of that for the card "B, 468," by the methods of torsions, the somewhat smaller value of which being due probably to the less favorable conditions under which the observations by torsion were made for that card.

It will thus be seen that the magnet-power of the navy-card, while somewhat more than twice that of card "B, 468," is less than that of card "D, 305," in the ratio of 1.000 to 1.450.

It will also be noticed, in comparing the oscillation-times and moments of inertia in the second and fourth columns of Table II., that a longer oscillation-time is not a certain indication of a lower magnet-power, unless due account be taken of the moment of inertia. Thus, the oscillation-time of the navy-card is about thirteen per cent. greater than that of card "B, 468," but its moment of inertia is nearly three times as great, so that the magnet-power is, on the whole, more than twice as great as that of the latter. On the other hand, as compared with the card "D, 305," the oscillation-time of the navy-card is still greater, but its moment of inertia is actually smaller, so that in this case the magnet-power is smaller, as it should be, than that of the card "D, 305."

Although, as shown by these observa-

tions, there is a good comparative degree of magnet-power in the navy-card, my principal doubt is, at present, in regard to the question whether we have yet reached the practical limit of magnetic development to which the card may be judiciously pushed. No case even of apparent deficiency in the magnet-power of this card has ever been brought to my notice; and my doubt on the point is, therefore, not based on the supposition of actual deficiency in this respect for ordinary circumstances, so much as on the conviction, heretofore expressed, that the compass-card should always possess a liberal reserve of magnet-power—up to the very limit which may be imposed by other conditions of card-construction—in order to provide for those large fluctuations in the directive force the effect of which might be to seriously diminish the moment of motive force, and thus to proportionally increase the defect of sensibility.

With respect to the question of magnetic permanency, our experience is too recent with the present process of magnet formation to permit the expression of any opinion as based upon actual results. This, however, may, I think, be said: that the recent changes in some of the details of that process are precisely such as, while obtaining a somewhat higher average of magnet-power in the magnet-piles, are well adapted to secure the most reliable state of permanency.

It should not be inferred that our previous experience has been particularly unfavorable with the results of the old process. So far as I am aware, not an instance has occurred, within several years past, of a reported discovery of any serious declension in magnet-power of the navy compass. Still, this is a kind of negative evidence, to which I am inclined to attach very little value, in the face of one positive fact to the contrary; and I hope to have the means hereafter of ascertaining the facts, on the return of our compasses to store after considerable periods of service on board ship.

In this respect, as in many others, there is an important advantage in favor of the navy compass—that the compass-card, being always delicately balanced on its pivot in the bowl, is in the best practicable condition for maintaining its magnet-power, other things remaining the same.

But, whatever may be revealed hereafter by a closer inquiry into the facts of our navy experience with the present form of compass, I am fully convinced that magnet deterioration is a much more prevalent and more serious evil than it is generally supposed to be by nautical men. I have had occasion, within a year past, to notice a number of instances of this kind, some of which were serious enough, and in one or two instances where I least suspected it, and by which I was considerably astonished.

The whole subject of the magnet-power of a marine-compass, in its twofold aspect of intensity and permanency, has appeared to me of such fundamental importance that I have determined to devote some time to its special study, with the hope that I may be able to clear up certain points not now as well established as I should be glad to have them.

Secondly, with respect to sensibility.—It will not be very difficult to understand why the navy compass should be expected to possess a high degree of sensibility.

Keeping in mind the condition already stated, that the defect of sensibility is equal to the moment of friction divided by the product of the magnet-power and directive force, let us consider the actual relations of these elements in the navy compass.

Now, as to this compass, the mean density of the submerged card admits of being so adjusted to the density of the liquid as to secure any desired buoyancy, and consequently produce any desired pressure of the card upon the pivot, however small, and whether upward or downward.

The minimum pressure at the pivot of the seven and a half inch card has thus been adjusted to about *sixty grains*, at the mean temperature of sixty degrees Fahrenheit, in order to provide for the variations of temperature and consequent changes in the density of the liquid ordinarily encountered at sea. It is necessary and sufficient that the least pressure to which it may ever be reduced shall be such as to secure actual contact at all times between the cap and the pivot; and, on the other hand, it is desirable that no greater excess of pressure

should be had, beyond the prescribed mean limit, than what is actually sufficient to satisfy the first condition.

It should be understood that these conditions of the card-pressure at the pivot are alike applicable, or nearly so, to the ordinary case of the downward pressure and to the special case of an upward pressure.

The relations of these pressures, downward and upward, to certain specified temperatures, for a liquid of normal mixture, at a pressure of 58 grains at sixty degrees, have been noted by Mr. Ritchie, as shown in the subjoined table :

Temperature of liquid	Pressure at Pivot.	
	Downward.	Upward.
Deg. Fah.	Grains.	Grains.
85	88	28
60	58	58
20	27	89
13	18	98

Again, so far as the choice of materials for the cap and pivot and the forming of the bearing-surfaces are concerned, the advantage is still with the Navy compass ; for, inasmuch as the bearing-pressure of the card is so greatly reduced, it will be allowable to use still harder materials and more sharply defined pivots than would be admissible in air compasses of the same size, whose lightest cards seldom fall below fifteen hundred grains ; and hence it follows that not only the mean radius of the bearing-surface, but the coefficient of friction, may be reduced to smaller values than they could have with the best possible form of air-compass card.

Accordingly, the moment of friction of the Navy compass is materially smaller than that of any air compass. Thus, without placing any estimate on the possible reduction of the two elements just named, the pressure alone, as compared with that of the lightest air-compass card, is not more than one twenty-fifth part, while it may be less than one sixtieth part as compared with that of the heavier cards.

And to this must be added the further advantage in favor of the Navy compass; that, in consequence of the extremely small working pressure of the card, the wear of the cap and pivot is so small, even during all the vicissitudes of the longest cruise, as not to materially increase the friction or diminish the sensibility. In some instances a perceptible wear of the agate in the cap has been observed on the return of the compasses for examination ; but in general the change is scarcely appreciable.

We have, then, in brief, two signal advantages of the Navy compass in point of sensibility : first, that of the extreme smallness of the moment of friction ; and, secondly, that of the proportionally small liability to change of that friction. And the second is scarcely inferior in importance to the first.

How much should be added, if anything, for the friction of the liquid in the cap, is a question which cannot be readily answered with the present state of our knowledge on this subject. That it must be very small, if, indeed, it be an appreciable element in the resistance of friction, appears quite certain, in view of such direct observations as I have been able to make on the sensibility of these compasses.

In order to illustrate the preceding view by the facts of experience, I shall first give the results of some recent inspection-tests for sensibility of a number of new Navy compasses received from the makers.

The test for sensibility consists in bringing the vertical cross-air of a telescope into precise coincidence with a division on the card-circle—as, for example, one of the zero-divisions ; then deflecting the card a *few* degrees* to one side by means of a small magnet, and allowing it to come to rest, to note the angle of set or defect of sensibility. The card-divisions are half-degrees ; and it is not difficult by means of the telescope to estimate tenths of a division, or twentieths of a degree, and to appreciate still smaller parts—as small even as one-sixtieth of a degree.

The tests were actually made by deflecting the card 3°, first to one side and then to the other, waiting in each case for the card to complete its vibrations and come to a perfect rest, before noting

* The *smaller* deflections are generally more severe tests than the larger ones.

the deviation of the zero-division from the cross-air. I thus obtained the following results, in an examination of 16 No. 1 or 7½-inch Navy compasses :

	Def.	Set.	
Of 12 compasses	3° E.	0°.00	Not appreciable.
	3 W.	0 .00	Not appreciable.
Of 1 compass	3 E.	0 .00 + W.	Appreciable.
	3 W.	0 .00	Not appreciable.
Of 1 compass	3 E.	0 .00	Not appreciable.
	3 W.	0 .00 + W.	Appreciable.
Of 1 compass	3 E.	0 .00 + W.	Appreciable.
	3 W.	0 .00 + E.	Appreciable.
Of 1 compass	3 E.	0 .05 W.	Error of 3′ W.
	3 W.	0 .05 W.	Error of 3′ W.

It is so seldom that any appreciable defect is observed in these tests for sensibility of the compasses that I am led to regard them, in their normal condition, as in this respect practically perfect.

I think it needs but a single observation, with the cross-hair of a telescope nicely adjusted upon a division on one of these cards, to be convinced of its exceeding delicacy of action. By observing in this manner the behaviour of a card after being deflected, as it approaches its final position of equilibrium, it will be seen to perform a series of minute oscillations about that position, so small and relatively so slow as to be scarcely appreciable by the unaided eye; suggesting most conclusively, I think, as already indicated on theoretical grounds, not only that the resistance of the medium at this stage is practically evanescent, but that the friction itself must be extremely small, in order that the moment of the motive forces acting at such small angles should be capable of overcoming it.

It might naturally be asked, after what has been said of the Navy compass, How does the test for sensibility result when applied to other compasses? In answer to such a question, I present the results of a few observations upon compasses of different makers, from the collection at the Bureau. With the exception of the three Navy compasses, they are all imported specimens of English makers ; partly liquid and partly air compasses. None has ever been in service, and all are kept with the cards freely suspended upon their pivots.

In making the experiments of the zero or N point of each card was first adjusted to nice coincidence with the east side of the *lubber-line*, and the deflections were made with the aid of a small magnet.

Navy, 6½-inch, No. 4794.		D, No. 1514 (liquid).		Navy, 7½-inch, No. 6217.		Navy, 10-inch, No. 4725.		H, 6½-inch (air).		B, No. 468, card J (air).		D, No. 305 (air), 7½-inch.		W (liquid).	
Def.	Pts.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.
1-2 E.	Pts.	Pts.	Pts.	°	°	°	°	Pts.	Pts.	°	°	°	°	°	°
1-2 W.	0	1-2 E.	0	5 W.	0.0	6 E.	0.0	1-2 E.	3-16 E.	5 E.	1.3 E.	5 W.	0.6 E.	6 W.	5 W.
3-4 E.	0	1-2 W.	1-16 E.	5 E.	0.0	6 W.	0.0	1-2 W.	1-8 W.	5 E.	0.0	5 E.	0.6 W.	19 E.	15 E.
3-4 W.	0	1 W.	1-8 E.	10 W.	0.0	10 E.	0.0 E.	1-2 E.	1-8 E.	5 W.	1.7 E.	5 E.	0.1 W.	9 W.	6 W.
	0	1 E.	1-8 W.	10 E.	0.0	10 W.	0.0 W.	1 E.	3-16 E.	5 W.	1.7 E.	5 E.	0.3 W.		
		2 E.	1-16 W.			20 W.	0.0	1 W.	3-16 E.	*	*	5 E.	0.5 E.		
		1 E.	1-8 W.					*	*	5 E.	2.0 W.	5 W.	0.7 W.		
		1 W.	1-8 E.					1-2 W.	3-8 W.	5 E.	2.0 W.	5 W.	0.1 W.		
								1-2 E.	3-16 W.	5 W.	0.1 E.	5 W.	0.2 W.		
										5 W.	0.6 E.	5 W.	0.3 W.		
										5 W.	0.7 W.	10 E.	0.5 E.		
										5 E.	2.0 W.	10 W.	0.8 W.		
												20 E.	0.1 E.		
												20 W.	0.2 W.		
												40 E.	1.0 W.		
												45 E.	0.1 W.		
												45 W.	0.7 W.		

Those experiments which are preceded by a * were made after having readjusted the N point of the lubber-line.

It has not been my purpose, in giving these results, to suggest comparisons which should be regarded as in the least degree invidious; nothing could be further from my own taste or the temper of mind with which these or any similar inquiries should be conducted. The compasses are of excellent workmanship, as those which I have seen of the well-known London makers generally are; and their deficiencies in this respect are to be attributed to the inherent defects of construction, if, at least, the preceding views are accepted; namely, to the sensibly large moment of friction (as compared with that of the Navy compass), and in one or two instances to the added defect of insufficient magnet-power, both of which, as we have seen, concurring in the production of an angle of set, or defect of sensibility.

Thirdly, with respect to steadiness.—The Navy compass is hardly less remarkable for steadiness than for sensibility. For this there are several reasons:

First. In the elevation of its centre of card-suspension, decidedly above both the centre of gravity and centre of buoyancy of the card.

Secondly. In the distribution of its heavy weights, not concentric with the centre, in two equal parallel chords, a little within the angle of 30 degrees from the parallel diameter, thus securing nearly equal moments of inertia about all diameters of the card.

Thirdly. In the use of a liquid-resisting medium, with the advantages resulting therefrom.

Fourthly. In the use of a buoyant skeleton-card, adjusted to a very small pressure at the pivot, from which result the several advantages in favor of steadiness already enumerated under the general head.

Fifthly. In the preponderating inertia of the liquid mass over its friction against the interior surface of the bowl, in consequence of which any sudden impulse given to the latter causes it to slip over or round the liquid without communicating any sensible motion to it and through it to the card.

A remarkable illustration of the steadiness of the Navy compass came under my observation, a year or two ago, at the Messrs. Ritchie's in Brookline. One of the earliest appliances devised by Mr. Ritchie, Senior, for the practical study of the behavior of a marine compass, is a very effective arrangement for testing its steadiness. This apparatus, which was erected in the attic story of the workshop, consisted of a strong framework, with moving parts on opposite trunnions, so as to admit of giving to a projecting head-piece rolling and pitching motions, mingled with occasional severe jars and shocks of the most exaggerated kind. He called it his "model of a ship"; but a ship could hardly live in a sea that would cause such motions.

I mounted this arrangement on one occasion with Mr. Ritchie, when we had one of the Navy 7½-inch compasses and one of the 7½-inch air compasses of the best construction. The two compasses were placed side by side on the projecting head-piece, about three feet apart. The effect, as seen by us from our more elevated position, was sufficiently striking. The card of the air compass not only would roll and vibrate in the most extraordinary manner, but frequently spin round and round; while the card of the liquid-compass had hardly any appreciable motion, the only apparent motion being a slight swing from left to right, and from right to left, and even this was synchronous with the alternate motions in azimuth of the head-piece on which the compasses were placed. Although I made no measurements to strictly confirm this impression, I could hardly resist the conviction that the small apparent motion of the card was in reality due to the actual swing in azimuth of the lubber-line. It seemed to me, from such a test, that the steadiness of the liquid-compass might justly be regarded as sensibly perfect.

Before concluding my review of the Navy compass, in which I have not hesitated to set forth with some prominence its manifold advantages, I should not omit, I think, to mention its defect, not as a peculiarity of this compass, but as inherent to the construction of all liquid compasses. It is the practical difficulty in effecting readjustments of the card equilibrium, if found necessary for the correction of defective horizontality, re-

sulting from any considerable changes in the magnetic dip.

This difficulty is simply one of inconvenience in opening the bowl to gain access to the card. It is easily enough managed by a person accustomed to it, with the appliances of the workshop, but it is a rather troublesome operation under different circumstances.

At present, the only remedy is the provision previously mentioned as one of the mechanical conditions of a steady card, namely, that of elevating the centre of suspension "well above" the centre of gravity of the card. By this means, it is intended to give to the card such an excess of stability as to overcome its tendency to obey the varying vertical component of the earth's magnetic force in different magnetic latitudes. That this provision is sufficient, within moderate limits of the change of dip, to prevent any appreciable error from defective horizontality, is, I think, quite probable; but how far it may be relied on, under more extreme changes, is a question that must be settled by careful observations with the opportunities that may be furnished by practical experience. So far as I am aware, not an instance has been reported to the Bureau of Navigation, during all the Navy experience with this compass of any difficulty in this particular, or of any apprehended error from this source.

But, as remarked in another case, merely negative evidence (or, in this case, the absence of any express reference to this matter, in the reports of navigating officers) can hardly be accepted as conclusive that it is entirely safe to neglect this possible source of error when sailing in high southern latitudes.

Nevertheless, I apprehend no serious difficulty in providing a practical remedy for this trouble, should it ever be deemed necessary or expedient.

Another objection has sometimes been made to this compass, that it is inconvenient to handle, as a portable instrument, on a tripod for observations on shore. This I shall dispose of in a word by saying that I can conceive of no occasion for the use of any marine compass on shore, when a good surveying compass, costing less than a third as much, would not be greatly preferable for convenience in handling, facility of use, and precision of results.

CONCLUSION.

I had originally intended to include in this communication some remarks on the several instrumental errors to which the marine compass is liable, besides the defective sensibility already noticed—errors essentially of compass-adjustment; and, especially, to have given some account of the adjustments of the Navy compass and of the degree of precision actually attained, as shown by our recent inspection-tests; but this must be deferred to some other occasion. It may suffice to say that I believe the Navy compass is susceptible of a high degree of precision, and that it may be furnished to the service in a condition which shall be practically perfect in this respect. I have said nothing of the *azimuth-circle*, because the compass itself is what claims our first attention; it being wholly fallacious to expect reliable results with the use of an azimuth-circle, however excellent, upon a compass which is liable to serious errors of adjustment and of defective sensibility.

It has doubtless been presumed, from the general tenor of what has been said on compass sensibility, that considerable importance is attached to this as one of the instrumental errors of the compass. In reality, I believe its importance can scarcely be over estimated. The errors of adjustment, even when quite large, are at least of a fixed character, and, if once definitely ascertained, may either be disregarded in ordinary cases of setting courses and in working up, or possibly allowed for in cases of greater urgency. It is otherwise with the error from defective sensibility. This, even at the outset, may be sufficiently serious; but, whether more or less so, there can be no certainty with air compasses, however excellent in workmanship, as to the amount of this error a few weeks later after a little rough weather at sea.

It is sometimes asked, Of what use is all this refinement of an instrument (generally concluded to be incapable of precision), so long as the navigator is unable to profit by it, and when, if he could, he is well enough satisfied if he can steer his courses to the nearest quarter of a point?

To this it may be said that, if we concede the sufficiency of such steering in an open sea (although there might be some who might regard it as hardly close enough in these days of "swiftest transit by the shortest route"), how is the navigator to be certain of doing even that with a compass whose instrumental errors, unknown alike in name and amount, may be much greater than the assigned limit to his error of observation; and especially when, in addition to the assumed errors of observation and the unknwn errors of the instrument, the compass error is further complicated by the uncertainties of the variation and the deviation?

My own conviction is, as the result of considerable study of the subject, that, in view of the inevitable errors of observation to which the compass is liable under the trying circumstances of its use at sea, it should be our object, in the first place, to insure in the construction of this instrument not only its practically perfect condition when put on board ship, but its continuance sensibly in that condition during at least one cruise of the ship; and, in the second place, to facilitate the determination of the magnetic variation and compass deviation, considered as compass errors in the reduction to the meridian, and to bring the uncertainties of these determinations within such definite limits as it may be possible to assign with a sufficient knowledge of the circumstrnces of the case.

PERIODS OF TRANSITION IN ARCHITECTURAL STYLE; AND IS THE PRESENT DAY ONE?

By Mr. A. PAYNE, A. R. I. B. A.

From "The Architect."

The question of style in architecture occupies an entirely different position in the present day from what it had ever occupied before. For instance, in the present day we may find in almost every city in Europe a street which has perhaps a Gothic church, a Greek public building, a Renaissance mansion, a Byzantine synogogue, and nineteenth century shops, all within the space of a few yards. But antiquity proves to us that an ancient Egyptian built in Egyptian, a Greek in Greek, a Gothic builder in Gothic; and why is it that we do not always build in the style of the nineteenth century? And what is the style of the nineteenth century? Why did the Romans adopt Greek architecture? Why was it abandoned by degrees from the third or fourth century? What caused so-called Gothic architecture to arise? Why did it come to a sudden stop in the sixteenth century? Why was it revived again in the nineteenth? Where are we in architecture, and whither are we going?

These are all momentous questions; and the theory which he ventured to bring forward to account for these changes was as follows:—In all ages the arts of mankind form a mirror in which we may perceive their intellectual, and sometimes even their moral development, acted upon and reacted upon by the circumstances in which they were placed. Thus, wherever a great intellectual development is formed among mankind—such a development, for example, as is produced by a new birth of religious ideas, there also will be found growing up a new style of architecture and a new civilization. In applying this theory to the history of the world, it might be said that the palmy days of Classic art were the heroic days of Greece. The Greeks possessed a religion of which a writer has said that "the life of the Deity was blended with all that exists in nature, and found its consummation in man." Every human faculty seemed by them to have been educated and carried to the very highest degree of culture, and in nothing did they achieve greater triumph than in the arts of sculpture and architecture. From the zenith of Greece a few centuries take us to another and equally extraordinary development of

Classic civilization—that of Rome—a kindred nation, springing from the same generic race, and with the same religion and the same architecture, but of a very different character. The ancient Roman despised learning and intellectual culture, being content to borrow his literature and his arts from the Greeks; he was a man of action, and took "material power" for his watchword. And is not this character exactly typified in the works left by this great people—in the fact that they had no distinct architecture of their own, but only borrowed and debased that of the Greeks, and that all their best works were done by Greek artists? By nature the Roman was not an artist, he did not believe in imagination, he was the engineer of Classic times; and his character is represented by those straight roads he has left wherever he has spread his conquests, or by those gigantic aqueducts running miles away in the broad Campagna from the walls of Rome.

In coming to the dark ages and the decline of Rome, it is observed that even a superficial glance at the writers of those times will show that, alone with the breaking up of the imperial power, men's intellectual and religious ideas were in a state of confusion, amounting to chaos. On the one hand more superstitious reverence was paid to statues, and ceremonies in connection with them, coupled with fanatic zeal against misbelievers, while on the other hand philosophic skepticism prevailed. This state of confusion was attended by a moral degeneracy, and these times were also amongst the most fatal to art and civilization; the crumbling away of the good old edifice of Classic civilization, art, and religion, and the gorgeous grandeur of Rome, in the first and second centuries, was the prelude to the general decay. No sooner has one religion become perverted or unsuited to the age, than a new form or development of truth is found gradually leavening the world, inspiring the minds of men, and spreading far and wide its life-giving stream. So it was with the rise of the Christian religion, which warmed men's hearts with a higher virtue and self-denial than was ever possessed by the ancient Roman, and a more poetic imagery than was ever known to the ancient Greek. The deeds of saints soon took the place of those of gods and heroes, and the beneficent figure of Christ blotted out all other representations of deity.

It is not usual to assign the Christian religion as the primary cause of those great architectural changes which finally transformed the Classic temple and basilica into a Gothic minster, but the researches of ancient writers seem to point clearly in this direction. Considerable astonishment would be felt on first looking through Count Vogue's excellent work on Early Christian architecture, "Syria Centrale," in the discovery of the magnitude of the changes introduced in the architecture of buildings erected for Christian use so early as the third and fourth centuries; these changes plainly foreshadowing the subsequent Mediæval developments. Count Vogue says that the churches of Central Syria were "built on the system of the Pagan basilicas of the country. The last, however, are surmounted by a cupola, and present already the form of the grand churches of Constantinople." In fact, if we carefully study the plates in Count Vogue's admirable work, and then turn to Galzenberg's Sta. Sophia, and other Byzantine examples, the connection is too obvious to be mistaken, and forms a complete chain between the Classic examples and the last named magnificent church erected by the Emperor Justinian, in the seventh century. At this time the West of Europe was overrun by hordes of barbarians. Rome was in ruins, the seat of the empire, and the chief city of the world, was Constantinople, so that we might well expect to find in it, as is the case, the links of the chain which unites Classic and Christian art. What were the causes which led to these seeds springing up in the East being transplanted to the West of Europe about the tenth and eleventh centuries, and there producing such a plentiful harvest in the Middle Ages when completely freed from their Classic progenitors? Unquestionably the Crusades. The epoch between the seventh and tenth centuries witnessed the consolidation and civilization of Western Europe through the agency of Christianity. But meanwhile a new danger appeared in the East in the triumph of Mahomed, and the splendid military achievements of his followers. Everywhere the unbelievers seemed to

triumph, and Christendom trembled for the fate of the Holy Land. Then followed the Crusades, and it is impossible not to perceive the immense impetus given about this time to the arts. At this period we can trace from existing buildings the streams of architecture as they flowed along the most used routes from Syria. Noticing the influences of this Byzantine stream as evidenced in the planting of a cathedral at Athens, and magnificent church of St. Mark at Venice, besides other minor churches, Mr. Payne remarked that Italy seemed also to catch the contagion, and to awake from her lethargy, and the Romanesque style in its more mature form arose, evincing a strong blending of the Syrian, and Eastern, and Classic elements. The style appears to have had its origin some centuries earlier at Ravenna, a seaport in close connection with the East. But in the eleventh century it gathers new impetus, and in the following century it gives birth to a host of noble examples in the northern cities of Italy. There was also a stream of this style running through the heart of Europe, nearly to the shores of the Northern Ocean. From the time of the Romans to the present, one of the great roadways between Italy and the North of Europe has been from Milan, over the Splugen Pass, to the present Coire, in Switzerland, and then down the Rhine to the German Sea. It is interesting to watch the stream of the Romanesque style running along this route, planting a little church at Coire among the mountains, a beautiful example in the Cathedral and cloisters of Zurich; and studding the banks of the Rhine with numerous examples, with the round arches and other characteristics of the Romanesque and Syrian styles, long after the surrounding countries were practising the pointed style even in its later developments. Indeed, at Aix-la-Chapelle, not far from this route, we may notice Eastern influence as early as the eighth century in the round church at Charlemagne, which is singularly like the churches of Ravenna. The same stream of Eastern ideas is perceptible on the other shores of the Mediterranean; it plants its mark in Sicily, and finds a welcome home in the South of France. Probably no country shows more completely the steps from Romano-Syrian to Northern Gothic than the South of France; and M. Viollet-le-Duc's "Dictionnaire," particularly under the article "Architecture," gives a series of examples which form a complete chain between the two styles, the author lucidly showing, step by step, how the changes took place, chiefly on account of problems to be solved in roofing over gigantic cathedrals in stone, when, after repeated trials, the pointed arch was found the only one to answer the purpose.

About the eleventh century the new style, now called Gothic, had fairly taken root in the powerful nations of England, France and Germany; and from the eleventh to the sixteenth centuries may be described as the very brightest period that has ever appeared for architecture. Let us compare the buildings erected during that period in our own land and those erected since. Look at the number of magnificent cathedrals—many of them in progress at the same time, and all of consummate art. Look at their splendid proportions, and variety of their conception, the exquisite beauty of their details; then turn to the countless abbeys and monasteries, all different from the cathedrals, and yet equally beautiful. Where can you find two alike, and where any instance of tameness or vulgarity? Turn to the other side of the page, and see what has been done since—in the three last centuries, far richer, more powerful, more scientific, and more able to build than those which went before. In our religious architecture of this age we have St. Paul's—a very noble building, though with scarcely a religious atmosphere, so to speak, about it—but the greater part of the page is blotted and smeared with an infinite number of tame and milk-and-water copies from the works of our forefathers—works which, if they could be beheld by the architects of Canterbury Cathedral or Westminster Abbey, would be enough to make them shiver in their tombs. But it may be said: "This is very bad for your theory; you claim a connection between intellectual and moral development and architecture, and yet you endeavor to show that this present age of light, which had its dawn at the Reformation and the revival of learning, cannot hold a candle in the art of architecture to the dark ages of Feudalism." But are we quite

correct in calling those the Dark Ages? The great characteristic of modern times is an immense development of material and physical science; but is it not possible that this exclusive attention to the material concerns may be a sign of the degeneracy of the age? May not this be shown by the immense superiority of the architecture of the Middle Ages over ours? For we must remember that architecture is not engineering, nor a material science, but a fine art which has its spring deep in the inner and spiritual part of our nature. But is this any reason why we should endeavor to go back again, architecturally speaking, to the Middle Ages? Surely not. In the words of Longfellow (slightly altered):

> We now restore the ancient fane,
> And tower and turret build again;
> The rest we cannot re-instate;
> Ourselves we cannot recreate,
> Nor set our souls to the same key,
> Of the remembered harmony.

Witness how rapidly the Gothic revival has run through all the changes backwards from Tudor to Early English, and after looking in vain for rest for the sole of her foot, is now either taking a dive into the abyss called "Queen Anne," or soaring aloft to woo the long-forgotten Romanesque. Witness how it chiefly obtains in the religious world—a world which, one may say, still lives or endeavors to live in the atmosphere of the Middle Ages. Witness what modifications it requires before adaptation to secular buildings. Witness how the mass of the people regard it as a thing for artists to amuse themselves with, but in which the public have no concern except to restrain its vagaries when they have to pay for them. No, if their be any truth in the theory here advanced that architecture and moral and mental development keep equal step and go hand in hand, we can as soon go back to the manners, habits and thoughts of the Middle Ages as induce the mass of the people to adopt Mediæval as national architecture. And it of course equally follows that we can as soon go back to the manners, customs and religion of ancient Rome or Greece as adopt their architecture as entirely ours in every detail.

It has been said by some that modern engineers have taken up the mantle left by our Mediævál forefathers, and in some respects this may be true; but as a rule engineers ignore the chief characteristic of architecture as a fine art. All honor to the skill and science of those men who had produced such stupendous works, and so immensely added to our convenience in this century. Nevertheless, unless constructors make beauty a *sine qua non* of their works, they are not architects properly so called. What appears to be wanted is for engineering skill and architectural love of beauty to act and react upon one another. If many architectural designs were submitted to the practical views of an engineer and then returned to their designer, no doubt much benefit would result. Looking at the architectural world, we notice confusion and conflicting ideas in modern times as to style; and looking to the religious world, we observe, as we might expect, an equal confusion. But it needs no prophet's eye to discern that out of chaotic existing elements a glorious picture may be preparing. Never before have all the lessons of the past been so completely laid before the present. Never have there been such skillful workmen, so many building materials, and such power to manipulate them. Yet something is wanting. What is that something? Firstly, a general love of beauty in everything diffused through all classes of the community; and, secondly, fresh and original thought brought to bear upon the architectural problems of the day—not too much trammeled by the past—the rejection of all architectural features not required by modern needs, and the adoption of modern building materials, such as iron, in the best manner. These are the principles which have developed the noble styles of the past, and why should they not give birth to the yet more noble styles of the future?

According to the *Globe* a considerable saving in the cost of the fuel supply on the China and Australian stations will, probably, be effected by the introduction of Wollingong coal as a substitute for Welsh on board her Majesty's ships employed on the stations named. We hear, however, that North country coal will be used to mix with the Australian in the proportion of one-third.

THE EFFECTS OF THE SUN'S ROTATION AND THE MOON'S REVOLUTION ON THE EARTH'S MAGNETISM.

By J. ALLAN BROUN, F. R. S.

From "Nature."

When the mean horizontal force of the earth's magnetism for each day of the year has been deduced from well-corrected observations of the bifilar magneto-meter, and the results have been projected in the usual way, the curves thus obtained show successions of maxima and minima occurring in some instances at nearly equal intervals and in others abruptly and apparently without law. It has been found that these changes are experienced similarly at all stations where observatories have been placed on the earth's surface; they are therefore variations of the magnetic force of the whole earth. The results now considered, though derived from the observations at a single station, may thus be accepted as true generally for all places.

In the projection of the daily mean forces observed at Makerstoun in 1844, the first and last quarters of the year showed large oscillations of the earth's magnetic force, the maxima occurring near the times of new moon and the minima near those of full moon; the ranges of the oscillations were not equally great, and the oscillation disappeared in the months near midsummer. The mean result for the whole year seemed to show that great changes of the earth's magnetic force were due to the moon's position relatively to the earth and sun; but no explanation could be offered for the apparent irregularities in the lunar action. Eleven years later (in 1857), while discussing observations made near the equator, I became persuaded that the variations in question were really due to the sun's rotation on his axis. The result of a re-examination of the Makerstoun observations gave a mean period of nearly twenty-six days for the most probable duration of the magnetic oscillation.

Astronemers who till then had occupied themselves with the determination of the time of the solar rotation has found for it from 27.3 to 27.7 days. It was difficult, in the face of this result, to suppose that the magnets were better acquainted with the true time of the sun's rotation than the eminent observers, who, with the best telescopes, had watched the movements of the solar spots; and it was suggested that a movement of the sun's magnetic poles might explain the difference of the periods obtained. More recently, however, it has been found that the spots give considerably different times for the sun's rotation, and especially that those nearest the solar equator indicate, as Spoerer has shown, a period of 26.3 days, thus approaching nearly to that obtained previously from the magnetic observations. Dr. Hornstein, director of the Prague Observatory, discovered, independently, nearly the same period from his observations in 1870.

There still remained for explanation the irregularities already noticed in the length and ranges of single oscillations. I, on the reconsideration of all the discussions previoulsy made by him, arrived some time ago at the conclusion that the results obtained for the solar and lunar actions did not exclude each other, but that both sun and moon were concerned in the changes of the earth's magnetic intensity; and that possibly the variations in the character of the single oscillations were due to the sun and moon sometimes acting in the same and sometimes in opposite directions; just as in the case of the oceanic tides, for which the differences would be even greater were the solar more nearly equal to the lunar action.

This conclusion is put to the test; the mean variations derived from the observations for each of two successive years are calculated for periods of 26, of 27.3, and of 29.53 days, the two latter being the times of the lunar, tropical, and synodical revolutions respectively. The variations for each of these three periods corresponding to the positions of the

moon and of a given solar meridian for each day of the year are then added together; the sums should represent the total actions of the two bodies for each day, and if no other causes are in question, they should agree with the observed variations.

I have shown that when the calculated results are projected so as to form a red curve, on the same mean line as a black curve representing the observations, the two agree very nearly with each other throughout the two years. The different durations and ranges of single oscillations, and the total disappearance of the latter in certain months, are found to be produced, as was supposed, by the greater or lesser agreement or opposition of the three actions.

These results demonstrate, I think, not only that the sun's rotation and the moon's revolutions produce variations of the earth's magnetic force, but that all the marked variations are really due to these causes.

There appears to be one exception to the generality of this conclusion, in sudden great changes, generally diminutions, of the earth's magnetism, which appear of variable magnitude and apparently at irregular intervals. I have examined these cases, and find that if a considerable diminution of intensity happen suddenly when a given solar meridian is in the same plane with the earth, that a similar sudden diminution generally occurs twenty-six days or some multiple of twenty six-days after, when the same solar meridian and the earth are again in the same plane. In one case the sudden loss of force begins five times in succession at the exact interval of twenty-six days.

If we examine these cases of successive disturbance when a given solar meridian arrives opposite the earth, we are induced to conclude either that the solar action exists only for this position, that is to say, that the earth is its cause; or that the action is continuous, but, unlike light and heat, is propagated only in one direction (or plane); or, which seems more probable, that the medium through which these actions are transmitted proceeds from the sun, is not uniformly distributed around it, nor always distributed in the same way. This idea may aid in explaining many facts in terrestrial magnetism for which hitherto no clue has existed.

We arrive then at the conclusions that the variations of the daily mean magnetic force are due to causes external to the earth, depending on the sun's and moon's motions; that all the principal variations of this force can be calculated approximately for each day in twelve months, on the hypothesis that the actions of these bodies are constant throughout the year for the same positions relative to the earth; and that the great magnetic disturbances (accompanied by the aurora borealis) are due to actions proceeding from certain parts of the sun's surface, since so many of them repeat themselves at intervals of twenty six days, when the same solar point returns opposite the earth. It appears from other investigations that the sun's rotation produces marked effects on our atmosphere.

THE COMBUSTION OF COAL GAS TO PRODUCE HEAT, AND THE THEORY OF THE STRUCTURE OF FLAMES.

By JOHN WALLACE.

From "Journal of the Society of Arts."

Wherever heat is required it is wanted in a certain definable quantity. This quantity is constant for any given purpose; that is to say, whether the object is heating a building, heating or melting metals, cooking, or any of the numberless operations to which we apply it, the same operation, however, often repeated under the same conditions, requires the same amount of heat.

The quantity of heat produced in order to perform any operation is always in excess of that actually required, because the whole of it cannot be utilized.

Radiation, convection, and absorption are all at work to carry off as much as possible, and the amount thus lost depends in a great measure on the method we adopt in applying it. This is well exemplified in the weight of coal required to evaporate 10 lbs. of water in a steam-boiler of good, or of bad construction, or in the weight of coal used in different stoves or fire-places to heat a room of a given size. The value of any material as fuel depends principally on its freedom from incombustible matter, and the facility with which it may be burnt in any desired quantity. Coal gas possesses these properties in a very high degree, and the condition in which it is supplied to consumers renders it the best kind of fuel for every domestic purpose requiring heat.

In many manufactures gas is the only fuel suitable for numerous delicate operations requiring a certain heat under perfect control; indeed, the possession of such a means of producing heat has given rise to numerous thriving industries which could not prosper without it.

Ordinary London gas requires to combine with about 6½ times its own volume of atmospheric air in order to be completely burnt. It will not combine with more, but if it gets less, then part of the gas which could not find enough of oxygen will escape only partially burnt, in a condition very injurious to health.

When completely burnt, a cubic foot of gas will produce a definite quantity of heat, and although some makers and vendors of gas apparatus claim for their goods the property of increasing the effect I have just indicated, it is no more possible to do it than to increase a pint of new milk by adding water.

The chief points to be observed in using coal gas are, consequently—1st, to burn it in the most complete manner; and 2nd, to utilize as much as possible of the heat produced.

There are two methods of burning gas to produce heat, each having its own merits. In one case the gas is divided into a number of small jets exposing a very large aggregate surface to the action of the atmosphere. In the other case air is mixed with the gas before burning, so that only a part of the total combining quantity of air has to join the gas at the surface of the flame. This allows the surface to be greatly reduced, and the bulk of the flame to be increased, and consequently renders it possible to burn a greater quantity of gas than before in a given space.

The latter method, which is due to Professor Bunsen, is the one almost invariably adopted in burning large quantities. The gas can not only be burnt in much less space than formerly, but it gives off no smoke, and consequently deposits no soot on any surface which it may be required to heat.

I light the gas issuing from a tube half-an-inch in diameter, and you see a long straggling smoky flame. As it is only by contact with the atmosphere that combustion can be supported, the gas has to expose a considerable surface to the air in order to get its supply. There is a hollow space in this flame extending to at least two-thirds of its height and full of gas which can only burn when it meets the oxygen. The sheath of flame surrounding this hollow space represents that part of the gas already under the influence of the oxygen, and the thickness of the sheath may represent the distance to which the oxygen penetrates before it is completely combined with the gas. If a vessel of water or other cool substance were placed over this flame a coating of soot would soon be deposited. But the moment I admit air to mix with the gas below the flame, the flame contracts to at least one-sixth of its previous size, the illuminating power disappears, and all the heat the large flame gave out is now produced by the smaller one. This flame deposits no soot, but on the contrary, will burn it off a coated surface.

Returning to the smoky flame, I coat a piece of tinplate with solid carbon which has suddenly been changed from the invisible and gaseous form into a wonderfully fine black powder; and now admitting the air, the flame shrinks and intensifies, the carbon is again transformed, and is now carbonic acid gas.

Bunsen, or atmospheric burners, no matter what their form may be, all possess certain essential parts in common. There is a gas-jet orifice, and, in close proximity, one or more air openings. There is a chamber where the gas

and air mix, and there is an outlet where the mixture burns.

Here is the simplest known form of Bunsen burner. It consists of a straight upright tube with a gas-jet orifice at the bottom and holes at each side of the jet, through which air is drawn by the inductive force of the gas. On removing the tube and lighting the jet the gas burns in a long pencil from the orifice, but, when the tube or mixing chamber is put on, the gas must burn at the top.

If the gas should light inside, then combustion is interfered with, and partially burnt gas begins to escape, producing that sickening smell which has brought the Bunsen burner so often into disrepute. The Patent office bears witness to scores of inventions devised to obviate this defect, and it is my purpose to exhibit to you several forms of apparatus designed to avoid this most inconvenient tendency.

I shall now direct your attention to the appearance of the flame, as it is in all cases an unfailing index of the value of the burner for practical purposes. Not only must the proper proportion of air be mixed with the gas, it must be mixed intimately, otherwise the flame will be irregular, produce a roaring noise, and be liable to light within on a slight change of pressure. The roaring appears to be caused by certain parts of the column of gas and air having explosive proportions which ignite and burn more readily than the rest. These explosions are so rapid as sometimes to produce a musical note. This irregular mixture may be cured in the common burner by lengthening the tube and by other methods.

Here is a burner one inch in diameter, with a flame which shows all the peculiarities of good combustion. The flame has a hollow space within represented by a most brilliant emerald green cone resting on the tube. Above and around this is a clear amber colored flame. The cone has a sparkling irregular surface, and the flame shows a strong disposition to "light down," indicating an imperfect mixture of air and gas in the tube. To render the admixture more complete I shall put into the tube a piece of sheet metal folded in such a manner as to divide the tube into several flat passages. The flame is now quite steady, although the air openings at the base of the tube are fully open, and the gas may be turned up and down within wide limits with perfect safety. In this case the surfaces against which the gas passes give it a rolling or eddying movement which thoroughly mixes the gas and air before they reach the flame. A mass of loosely twisted wire will produce nearly the same effect, but it reduces too much the velocity of the current.

Another, and a more complete method employed to adjust the proportion of air is exemplified in the "cam" burner.

At the base of the tube is a gas cock, having an eccentric fixed on the plug or key, which lifts the air slide in such a manner as to adjust the gas and air at one movement. The curves on the cam or eccentric are so made that on one side the maximum amount of air is admitted, producing an oxydizing flame, while on the other side the curve allows a less amount of air, producing a deoxydizing flame. By quickly reversing the cock, the air slide is closed, and pure gas burns at the top of the tube. In addition to this, the burner tube is hinged so as to incline to any angle, making on the whole a very useful laboratory burner.

To illustrate the intensity of the heat of the flame, I shall expose to it a piece of stout copper wire. It becomes rapidly red hot, then a pale golden color, and now it has fallen in molten drops into the vessel of water placed below the flame. Copper is estimated to melt at 2,245° F.

It is not always convenient to use a burner of this description, because if the pressure were to be suddenly lowered independent of the gas cock and cam, it would light down and cause the usual nuisance.

In order to have a burner which shall be absolutely safe and reliable under all variations of pressure and quality of gas, another form of burner must be used, of a class represented by the tangent burner.

It consists of a circular chamber, into which the jet of gas enters at a tangent, drawing with it the air necessary for preadmixture. The compound eddies round the chamber escaping finally at the tube a perfect mixture. A diaphragm of wire gauze below the tube prevents the flame from getting into the chamber,

and a covering of the same material protects the jet orifice of the gas.

This burner may be made of various sizes, of which I have here an example with twelve flames.

It is now time to inquire how much air is mixed with the gas previous to combustion. The Tables I. and II. contain the desired information. They were made upon Newcastle coal gas, combining with

Experiments on the Proportion of Gas and Air, Mixed Previous to Combustion, in Wallace's Burner.

Table I.—*Pressure of Gas and Air six-tenths of an inch.*

Experiments.	Height of Inner Cone.	Height of Outer Flame.	Volume of Gas per Hour.	Volume of Air per Hour.
	Inches.	Inches.	Cubic feet.	Cubic feet.
No. 1....................	.29	2.75	6.00	8.22
No. 2....................	1.00	2.55	6.00	6.00
No. 3....................	1.55*	3.30	5.82	3.66

Table II.—*Pressure of Gas and Air fifteen-tenths of an inch.*

Experiments.	Height of Inner Cone.	Height of Outer Flame.	Volume of Gas per Hour.	Volume of Air per Hour.
	Inches.	Inches.	Cubic feet.	Cubic feet.
No. 4....................	.55	3.30	8 84	12.72
No. 5....................	1.00	3.30	8.88	10.92
No. 6....................	2.40*	4.30	9.00	6.96

about 6½ volumes of air, and as the same coal is used to make London gas, they will serve to represent the results of burning London gas under the same circumstances. They show how much air may safely be mixed previous to combustion in a burner of a given size.

The burner used for this purpose had a tube seven-sixteenths of an inch inside diameter. The consumption of gas was maintained as nearly uniform as possible.

The tables indicate the changes in the appearance of the flames as the pre-admixture of air varied. The result showed that one and a half volumes of air was the maximum limit of preadmixture with a seven-sixteenth inch burner; if the air exceeded that amount, the flame would go down the tube and burn within. If, on the other hand, less than 65 per cent. of air were mixed previous to combustion, the flame began to burn imperfectly and deposit soot. There must always exist a certain proportion between the diameter of a burner tube, the quantity of gas passing through it, and the quantity of air mixed with the gas. A well-made burner will be equally efficient with gas at all pressures, from three-eighths of an inch up to any number of feet on a water column; and it is difficult to say how much gas may be burned through one tube. We have already observed that as the pre-admixture of air increases, the flame becomes smaller and more intense. Bearing in mind, then, that the nearer a substance to be heated is placed to the source of heat, the more rapidly the heat passes into it, we find that a vessel of water may be placed nearer the centre of the flame without interfering with combustion. There is also less risk of the flame being fouled in its own products when the amount of air it takes up while burning is reduced to a minimum.

In Table III. are the results of three trials made with the illuminating burner against the Bunsen burner. A vessel of tin-plate, containing one pint of water,

* Cone almost imperceptible, with short white tail.

was placed over an illuminating burner of the batswing form at a height above the flames chosen out of three trials at the best position. The same vessel and quantity of water were placed over the Bunsen burner with like precautions :

TABLE III.—*Gas burning at the rate of* 4.5 *cubic feet per hour.*

Experiments.	First.	Second.	Third.	Average.
	min. sec.	min. sec.	min. sec.	min. sec.
Batswing......................	12.43	12.45	12.48	12.45
Bunsen...	9.32	9.32	9.33	9.32

The results of this experiment serve to confirm what has just been stated. With gas burning in both cases at the rate of four and a-half cubic feet per hour, the water was boiled in 9 minutes 32 seconds by the Bunsen burner, whereas the batswing required 12 minutes 45 seconds. The balance in favor of the former is, therefore, 3 minutes 13 seconds, or 25 per cent. As the diameter of the Bunsen burner is increased it becomes more and more difficult to obtain a good and steady flame. Increase of length gives the air and gas more time to mix and produce a regular flame, but the slightest disturbance causes it to strike down. The experiment with the folded plate and the twisted wire as slight obstructions made a certain improvement, but could not be called a complete remedy. The rose top is the best known appliance, but when made of large size the combustion in the interior of the flame becomes imperfect, and, after all, it will not bear turning low without striking down. Another necessary condition also presents itself, increasing the difficulty of obtaining a good large flame. The proportion of air mixed previous to combustion must be greatly augmented because, the surface of the flame (which takes up the remainder of the air to render combustion complete) does not increase in the same ratio as the volume of the flame. If the flame be long and straggling, although giving off no unburnt products, it will certainly deposit soot when applied to the cold surface of a vessel of water ; it therefore becomes a matter of the greatest importance, that the burner be of a form that is free from the risk of striking back when lighted. To meet this difficulty the perforated cap has been devised, which by reversing the usual principle of construction, gives the most remarkable results. Instead of regulating the admission of air from below by partially closing the air orifices, it is done at the top by back pressure.

A cap of perforated metallic plate is fitted over the top of the burner tube and made to slide up and down, so as to adjust the number of openings through which the air and gas are to escape into the flame. The cap offers more or less impediment to the upward passage of the gas, and thus controls and regulates its power of drawing in air at the bottom. This burner has been found capable of burning every kind of coal gas with equal facility. When lit, and adjusted to the maximum amount of air, the cap is studded with brilliant green beads forming the base of the flame ; each bead corresponding with one of the perforations, while above you see a flame which is solid to the centre, and without that hollow inner space which has hitherto been considered a peculiar feature of all round flames.

A piece of fine wire put across the flame close to the cap is incandescent along the whole length enveloped in the flame coming from a burner two inches in diameter, and consuming forty feet of gas per hour. When I partially close the air openings, a hollow conical space immediately appears in the flame, and the wire cools to blackness. On again admitting the air the wire becomes immediately incandescent, and the flame is solid as before. In order to make the appearance of the beads more distinct, I shall use a cap, with much coarser perforations, which, if carefully lighted, makes a flame of marvellous beauty. The cap is now studded with an array of gems whose brilliancy would pale that

of the brightest emeralds. Their color is entirely on the surface, for they are hollow, and filled with the unburnt mixture of air and gas, and they fade and merge into each other on the slightest interruption of the air supply at the base of the tube.

These experiments all indicate that a great increase must have taken place in the amount of air mixed previous to combustion. This supposition has already been confirmed by measurement, proving that a burner two inches in diameter will burn safely a mixture containing 4.6 volumes of air per volume of gas.

Spectrum analysis has not yet thrown much light on the peculiarities of this flame. The carbon lines are exceedingly brilliant in the spectrum of the green beads, but the condition of combustion indicated is not clearly defined. It was at first thought possible that the increased temperature of the flame might cause a combination with the nitrogen of the atmosphere mixed with the gas, but a mixture of pure oxygen and coal gas gave the same spectrum as before, so that the nitrogen may be supposed to pass through it unaffected.

The application of coal gas to cooking seems to have had a fair amount of attention from competent men, and good and useful apparatus are easily obtainable; but it is otherwise with the gas stove, which shows scarcely any improvement for the past twenty years. It has been much ornamented, and that is all. The largest burner put in the smallest case that will hold it without becoming too hot seems to be the *ne plus ultra* of a gas stove. If a chimney is used, it is put at the hottest part of the stove case, so as to carry off the heat as well as the products of combustion, or still worse, the burner is put in a common fireplace, and at least seven-eighths of the heat go up the chimney. There is no more extravagant method of using gas than this.

Every one who has seen the coal stove in use on the Continent must be aware that its great heating power is due to a large radiating surface, and nothing else than a large radiating surface would give such a result. The same rule applies to the gas stove, which should be at least six feet high, and so arranged internally that the products of combustion should pass over the whole surface before escaping. The diagram shown represents a section of a gas stove six feet high and fifteen inches diameter, with a partition dividing it into two parts from the bottom to within six inches of the top. The products of combustion from the burner, pass up to the top of the division, and then down the other division, escaping on a level with the burner, after having traveled nearly twelve feet over a thin iron plate forming the radiating surface of the stove. The hot spent gases not only pass over a large heating surface, but they travel slowly, allowing the greatest time for the heat to pass through.

The speed of the draught (being regulated by the difference of temperature of the two columns) is always in proportion to the amount of gas being burnt, and the result is a balanced draught which never requires the control of a damper.

Let me show you by experiment the advantage of this arrangement.

A syphon of stove piping represents the stove case with its two divisions, and a small burner is placed below one end. The products of combustion pass up one half of the syphon and down the other, escaping at the level of the burner. To render this apparent I pass some smoke up from beside the burner, and you presently see it emerge at the outlet, showing that there is a continuous current through. The products of combustion are losing heat through the sides of the pipe as they travel along it, and the thermometers fixed half way along, and at the end, will give us an idea of the rate of radiation. The thermometer at the bend of the syphon stands at 220 degrees Fahrenheit, and that at the bottom or outlet indicates 95 degrees Fahrenheit, so the difference between these two temperatures represents what would be the loss from a gas stove, if the chimney were put at the top instead of at the bottom, and shows the absurdity of placing the outlet at the top.

The disposal of the products of combustion is the next matter for attention, for, although, they may be carefully turned into a chimney, they may be unable to ascend by reason of down draughts. This difficulty often occurs in heating conservatories having low

chimneys, and situated frequently in places where the force of the wind accumulates. There is the risk of extinguishing the gas which may afterwards escape, causing serious risk of explosion, and there is also the danger of having the products of combustion blown in among the plants, which would soon kill them.

The problem then is, how to prevent the down draught without closing the chimney, and thereby arresting the products.

The disturbing force of the wind down the chimney must be met by another equal force acting at the same time in an opposite direction. These two forces will meet and neutralize each other, and the products will continue to escape, as in calm weather.

I shall again have recourse to experiment, to show how this may be done.

Here is a box representing the stove case, which is placed below the syphon pipe. A flame burns in the box, which is air-tight with the exception of a small tube supplying air to the flame. The outlet of the syphon is extended so as to terminate close to the air supply tube. Both these tubes open in the same direction, and the orifices may be at any distance from the burner. We have now the outlet and inlet terminating so nearly together as to receive the force of the wind at the same time, and, although I make a violent current of air pass against these openings, you see through the glass window of the box that the flame suffers no material disturbance.

A gas heating stove cannot be said to be complete until it is fitted with an automatic regulator, which will only allow the gas to be burnt at such times and in such quantity as will insure the desired temperature.

I shall now show you an apparatus designed for this purpose, which owes its movement to the expansion and contraction of air confined in a closed vessel. Air is remarkable for the small amount of heat requisite to change its volume. An increase of one degree Fahr. will expand 491 cubic feet of air into 492 cubic feet; and, if it is not allowed to expand, by being confined, it will exert a pressure equal to a column of mercury one-sixteenth of an inch in height. A difference of a very few degrees, therefore, can easily accumulate sufficient force to close or open the gas orifice of a stove.

The second diagram is intended to show how this may be put into practice, and such a regulator will work on a difference of two degrees Fahr., lighting, adjusting, or extinguishing the burner as heat may be required, for weeks or months together.

The mode of action is as follows :—A thin copper cylinder of a certain capacity contains the air which is to regulate the gas by its expansion. This vessel is painted a dead black to render it the more susceptible to absorption or radiation of heat, and it has on it a small valve, the purpose of which will presently be described. A small pipe leads from the expansion chamber to one end of an invented syphon, containing mercury. The other end of the syphon has within it a tube suspended over the mercury, with its mouth at about one-eighth of an inch from the surface.

The gas to be burnt enters the cup at one side, and passes over the surface of the mercury into the central tube, up which it passes on its way to the burner in the direction of the arrows. In addition to this a tube takes a supply of gas to a small flame burning constantly beside the burner. As the air is confined in the vessel, the tube, and the cup, any increase of volume will depress the mercury in the cup, raise the level in the tube, and decrease the space below the central tube by which the gas escapes to the burner ; and if the air continues to expand, it will close it completely and cut off the gas. Then the surface of the mercury around the centre tube is acted on by the pressure of the gas while the surface within the tube is free, so the mercury within rises to a height proportionate to the pressure of the gas.

When the mercury begins to fall by reason of the cooling of the air in the expansion chamber, it still retains a higher level within the centre tube until its gravity overcomes the pressure of the gas, when it falls clear of the tube, allowing a free rush of gas to ignite the burner immediately by the aid of the constant flame. All that is necessary to set this regulator is to open the valve in the expansion chamber, and light the burner. When the desired temperature is obtained, the valve must be closed,

and a sample, as it were, of air at the desired temperature is shut up in the expansion chamber. Any alteration of temperature outside the chamber will affect the volume of the air within, causing a corresponding adjustment of the gas. If the gas were turned slowly on and off, there would be an escape each time it was lit and extinguished, but in this case the supply and cut off are sudden, while the adjustment is gradual.

With an apparatus of this kind a conservatory, for instance, may be heated with the greatest nicety. As sure as the thermometer falls below a given point, the gas will be turned on and lighted, and when the sun affords sufficient warmth, it will be extinguished until the temperature falls again.

That absence of sufficient heating surface, which has already been noticed in speaking of the ordinary gas stove, is equally remarkable in most of the hot water apparatus, where gas is the fuel used. Twenty-four inches is the maximum distance the heat is allowed to travel in contact with the boiler, and from eight to ten inches may be regarded as a fair average distance when speaking of the small apparatus of which the greatest number are sold. Is it any wonder that gas heating has been tried and condemned a hundred, nay, a thousand times; or that the public at large should be thoroughly satisfied that it has in it no element of true success.

I know of only one manufacturer whose hot-water apparatus shows any sign of thorough appreciation of the fuel he has to deal with. The apparatus is shown on diagram No. 3, which has been kindly lent by the inventor, Mr. Ezard, of Bradford, near Manchester.

The diagram represents a double range of hot-water pipes attached to a small boiler under which the burner is placed. Instead of carrying the chimney away from the top of the boiler, it is made to pass along the upper range of pipes, emerging at the return bend.

You will at once see how greatly the heating surface is increased, and this is not the only important advantage gained. The time of contact is extended in proportion, and the result is that the product of combustion escape at a temperature only slightly above that of the water. When we remember that water contains 3,234 times the quantity of heat which an equal bulk of air contains at the same sensible temperature, it will be evident that very little of the gas heat is going to waste.

No real progress can be made in the application of gas to heating until the following facts are fully recognized. No apparatus made to burn coal fuel is fit to be used for gas fuel, the condition necessary to insure good combustion being totally different. Gas fuel requires a large heating surface, and a very slow chimney draught, barely enough, in fact, to carry off the product; and this draught must not be disturbed.

Gas at 3s. 9d. per thousand feet costs 1½d. per lb., and yet it is now well known that cooking may be done with it not only better but more cheaply than with coal.

I shall now proceed to make a comparison between gas and coal as fuel for heating, and the figures will require very little to be added by way of comment.

Let us assume, as a basis, that coal costs the user 26s. per ton, and gas at 3s. 9d. per thousand feet in London, and on these data examine the cost of obtaining an equal amount of heat from the two substances.

In 1866, Dr. Letheby and Mr. F. J. Evans demonstrated that 1 lb. of coal completely burnt would produce the same amount of heat as 13 cubic feet of coal gas.

From the estimates of Dr. Neil Arnott, Mr. Edwards, author of "Our Domestic Fireplaces," and other authorities on this question of the heat utilized for heating a chamber by burning coal in a common open fireplace, it appears that on an average, one-eighth or 13 per cent. of the total heat of the coal is really available for the desired purpose. Eight pounds of coal would, therefore, be required to produce as much heat in a room as would be given off from a three-light chandelier burning 13 cubic feet of gas in one hour.

Their relative prices would be as follows:

	d.
8 lbs. of coal at 26s per ton............	1.112
13 cubic feet of gas at 3s. 9d. per 1,000.	.585
Difference............	527

In other words, the cost of the same

amount of heat in the two cases would be as 11d. to 6¼d., which is tantamount to saying that the coal heat costs 90 per cent. more than gas heat. As it is not wholesome to allow the products of combustion from a gas stove to escape into a room, a liberal sacrifice might be made to get rid of them by means of a chimney, without bringing up the cost of the gas to that of the coal.

There are certainly many methods of using coal which render it more economical than gas, but most of them are expensive to apply, and none possesses all the advantages of gas fuel. If the figures just quoted are to be relied on, gas is no longer to be regarded as a luxury for the wealthy alone. The poorest classes have generally the worst constructed fireplaces as regards heating power, and buying their coal in small quantities, they pay a higher price for it than do those who buy by the ton. It should be an inducement to the public to know that the use of gas in the daytime is more likely than anything else to reduce the price of it by giving uniform and complete employment for the apparatus at the gasworks, and it is neither impossible nor even improbable that at no very distant date coal or other gas may almost entirely supersede the fuel at present used in the dwellings of all our large towns.

There is one other application of gas heat to which it will on the present occasion be possible only to refer briefly. It is the raising of steam to drive small engines of not more than four horse-power. The demand for engines of this class is already very great, and a good substitute for the coal furnace is much needed, not only because it affects the insurance of a building, but also because a small fire requires much more vigilant attention than a larger one. There are already many gas-heated boilers in London and elsewhere, but they appear to be all constructed after the pattern of the coal-fired boiler, and the inevitable consequence must be a considerable waste of gas. The rules already detailed for the construction of heating apparatus apply equally to steam boilers. There must be the balanced draught, the large heating surface, and the greatest possible distance for the heat to travel before leaving the boiler. There must also be high steam pressure, and an automatic regulating valve on the gas-pipe, actuated by the boiler pressure, so as to turn the gas down as soon as the steam approaches the blowing off point, and thus use fuel only as the rate power is required.

Such a boiler is already in the hands of a well-known firm of engineers, who intend to manufacture it in conjunction with small sizes of the already famous Willan three-cylinder engine. Results of the most satisfactory character have confirmed the experiments already made, and an exceedingly useful and compact apparatus may be expected.

There are various facts among the foregoing remarks which, if summarized, may lead to some useful conclusions regarding the constitution of the solid flame. Let us take the well-known Bunsen flame as a basis of comparison. There is the conical space within the flame, then a sheath or envelope of flame described by Faraday as the zone of partial combustion, and outside of all a second sheath or envelope, the zone of complete combustion. Although air has been mixed with the gas before it reached the flame, it is not sufficient to render the gas combustible. The mixture of air and gas ignites first around the edge of the tube, because there it meets the oxygen most readily, but the centre of the rising column of gas and air has to travel to the top of the hollow cone before it can meet the oxygen of the air, which rushes into, and combines with, the flame, with extraordinary rapidity. The thickness of the flame surrounding the hollow cone represents the distance the oxygen travels before it is combined with the gas, previous to escaping upwards as carbonic acid at a temperature which greatly increases its volume. Part of the oxygen is arrested in the outer sheath or zone of perfect combustion, and part presumably passes into the zone of partial combustion, producing a carbonic oxyde flame, which, as its material passes into the outer part, receives its complement of oxygen, and becomes carbonic acid.

It has already been observed that small flames require less air pre-admixed than large ones; this is due to the greater surface which they present to the air in proportion to their bulk. The

oxygen has consequently a less distance to travel into them.

In Table No. 1, a 7-16th of an inch burner would only bear 1½ volumes pre-admixed before becoming solid, whereas a 2 inch burner would require a mixture of 4.6 volumes to solidify it. If the small burner received more than 1½ volumes, the flame immediately descended and burned within the tube, its position in the tube depending on the excess of the pre-admixture. Before the flame descended, it exhibited the bright green film across its base, indicating the best state of combustion, and it retained the green film even when burning half way down the tube.

Now, when we remember that it requires nearly 6½ volumes of air to consume the gas completely, it is evident that the amount pre-admixed is not enough even to produce a carbonic oxyde flame, which requires just one half of the total amount. If, then, the combustion is complete, the flame must receive its complement of oxygen through the top of the tube, making its way through and against the current of products of combustion, whose velocity is increased by expansion into six or seven times their original volume.

Leaving the small flame, let us turn to the large one. The primary conditions are here very different. In the first place it has only one tenth part of the surface in proportion to its bulk that the small flame has; and in the second, the amount of air pre-admixed is 4.6 volumes, or about 40 per cent. more than that necessary to produce a carbonic oxyde flame. The flame is perfectly solid, from the green beads where it commences, up to the top. There is no apparent difference in the temperature of the flame from the centre to the outside, and the green beads (those most delicate indexes of any change in the proportion of oxygen in any part), are exactly the same in color and size at the centre as at the outer edge. The platina wire when suddenly placed across the flame heats apparently at the same rate in every part immersed, so there is much reason to suppose that this is a carbonic acid flame having neither the zone of no combustion nor that of partial combustion.

It must not be regarded as a group of separate flames, as the beads have no separate supplies of air; besides, a solid flame can be produced without the perforated cap, by making a sufficiently intimate mixture of the air and gas, as in the case of the smaller flame. Since the green beads are so uniform in size and color, we may reasonably conclude that they are burning under the same conditions, and one of these conditions is that the two and a quarter volumes of air necessary to combustion of the gas must pass to the very centre of the flame, giving every bead a uniform and equal supply.

It wold be interesting to learn whether the nitrogen of the two and a quarter volumes of air accompanies the oxygen into the flame, or whether it is partially or wholly dissociated before combining.

The subject has been treated throughout from the point of view of an engineer rather than that of a chemist, and more with a view to getting at the simplest and best modes of burning coal gas rather than of analyzing the phenomena of combustion.

The work of the chemist has been a good deal limited by the apparatus with which he has experimented; and it is with a hope that an improved form of burner may assist in the further analysis of a most important subject, that the matter has been brought before you.

The sewage difficulty in the large towns in the United States is apparently becoming urgent. The drainage of a large city like New York cannot be poured with impunity even into an estuary almost filled with sea water, and the ebb and flow of the tide spreads the solid refuse that pours out of the sewers over a radius of nearly twenty miles. Looking forward to the probable increase of the city and the certain increase of the nuisance from sewage, it is now proposed to intercept the whole contents of the drains and carry them out to the sandy grounds of Navesink, where they will be filtered and made to produce, possibly, a good proportion of the animal consumption of vegetables. A company undertakes to do all this gratis, provided only that the privilege to make use of the sewage shall be given to it in perpetuity.

BRITISH IRON TRADE ASSOCIATION.

Inaugural Address of the President, Mr. G. T. CLARK.

Gentlemen: You have done me the honor of electing me as the President of our Association, and I am instructed that it is my duty, as it will be that of future Presidents, to commence their term of office by an Address.

He who finds himself in such a position naturally looks back to see what view his predecessors have taken of their duty, and, according to his taste or temperament, will either follow suit, or attempt to strike out something new. But I, unfortunately, preside over a new Association, and have, therefore, no indications what to avoid or what to follow. The channel I have to navigate is not as yet buoyed out. I have no skillful predecessor by whose wake I can steer safely through the narrows, nor are there as yet any wrecks on either hand to show where shoals or rocks may lie. Under such circumstances, I cannot afford to be ambitious, and therefore propose to confine myself to the humble but necessary duty of setting forth, as best I may, what, as it seems to me, should be the aims and objects of the Association. Our Association is composed of men who are largely concerned in and represent, what is not only one of the greatest branches of British industry, wielding an enormous capital, and giving employment, directly and indirectly, to hundreds of thousands of persons, but is also one which does not depend entirely or principally for its raw material upon foreign countries, and which, therefore, is less liable than some others to be affected by war or external disturbances, and is, besides, independent of climate or the uncertainty of the seasons. But although we do not necessarily exchange finished produce against raw material, it is not less the fact that we have extensive and intricate relations with foreign countries, and are called upon to take a keen and often a painful interest in their fiscal and customs' regulations. Moreover, the iron trade, including therein its subsidiary branch of the coal trade, is, beyond any other, exposed to the uncertainties which, in these days, attend upon the employment of labor, and has had, and it may be feared, is still destined to have, a larger experience than falls to the lot of other trades, of the modern difficulty, known as a "strike," which bears to the general prosperity of a trade very much the relation, whether for evil or for good, which is borne by war towards prosperity in general. For these reasons the Iron Trade Association claims to take a very forward place among the industrial representations of our country, and it will be for those, whom I have the honor to address, or who may afterwards become its members, by their contributions to its discussions or its transactions, to establish the position which it aspires to take up, and to do justice to the vast mechanical, industrial, and commercial interests, of which, with the Iron and Steel Institute, it is the representative.

Iron, if not the metal of highest price, has ever been that of the greatest value; that of which the world could least afford to be deprived; and it has played a more important part than any other mere material agent in the civilization of mankind. And if this be true of the earlier and the middle periods of the history of the world, it is still more remarkably so of the age in which we live, when the employment of iron in railways, in the fabric of ships, in bridge building, in floating docks, and for other purposes of construction, especially in large public buildings, has increased its production in a very marvelous manner, and has combined with other means, also of rapid growth, to alter all the conditions of the manufacture, and to produce a sudden and complete revolution in the trade. It is, moreover, observable that these changes excessive as they are, have not been brought about by war or violence, but by causes perfectly natural, though ordinarily slow in action, which during the last few years have operated with accelerated speed. Thus it has chanced that important trades, and considerable branches of manufacture, have sprung up or have decayed, or been directed into other channels, with very unusual, not

to say unheard of, rapidity, demanding on the part of those engaged in them no common foresight, no ordinary promptitude of action, so to meet the altering circumstances as to escape ruin, if not to extract out of them advantage.

There was a time, and that not long since, when the iron trade of Great Britain was in the hands either of individuals or of companies of a strictly private character, composed of a small number of partners. In those days the disposable capital was limited, and the attention of the iron master was confined pretty closely to the details of his manufacture, and to the sale of his metal at the nearest port. His channel of conveyance was the canal; his ore, flux, and fuel, were raised very near to his furnaces. He left his works, or at any rate his district, but seldom, and if his trade, over any length of time, was unprofitable, he had no resource but to wind up and retire. There was but very little legislative interference with his business. I have heard some of the fathers of the trade relate, with much satisfaction, the part they took when Mr. Pitt proposed to lay a tax upon pig iron: how they went to London, formed a committee, and saw and expostulated with the Minister. To some of the smaller of these men, the event of their business lives was this one bit of legislative agitation, which to many of us is almost an annual anxiety and annoyance. At that time, too, commercial treaties were unusual, and there were no combinations worth mention among the workpeople, making necessary counter-combinations on the part of the employer. The ironmaster of that time troubled himself very little about the relations between labor and capital, and in fact regarded his business from what would now be considered a very narrow point of view.

And yet the old ironmasters, who were produced by and who perfected this bygone system, were a remarkable race of men. They were men of whom England had reason to be proud. They were mostly self-made, strong, firm, not to say obstinate in their will, very self-reliant, rough but not unpopular with their workpeople, of great kindness of disposition, and they possessed that rare and great gift the power of managing men. Such were Sir John Guest, the Crawshays and the Hills, in Wales; the Knights and the Darbys in Staffordshire, and the Bairds in Scotland. A sort of natural selection weeded out the weak, so that only the strong survived. The very term "Ironmaster," long applied in no other trade, has a strong flavor of power.

Men, circumstances and conditions are now changed, and changed within our generation, within the business life-time of many of us. The joint-stock system, which has brought immense capitals into the iron trade, and in many instances been worked to the advantage of all, has too often found combinations of shareholders who, after losing heavily, year after year, by the trade, are still willing to go on, of course to the utter ruin of those who cannot afford to carry on their works without profit, and to the serious injury even of those who from more favorable circumstances or more skillful management are yet able to live. To take a slight liberty with some well-known words, I may say:

> "———— The time has been
> That when the cash was out the firm would die
> And there an end. But now, they rise again
> With loans and preference shares upon their brows,
> And push us from our stools."

It is not too much to say that in certain districts of Britain some millions sterling have been expended in the last ten or twelve years in producing iron which has been sold at a loss, utterly deranging the ordinary relations between demand and supply, and producing in the long run immense discontent among those very bodies of workmen whose wages have thus been artificially raised. In an old country such as ours, so densely peopled, so highly industrious, and therefore filled with trade rivalries and competitions, there must necessarily be, in every trade, occasional and serious fluctuations, but there exists no branch of British industry in which the fluctuations have been so frequent, the alternations between prosperity and depression so severe, as in our own. In the iron trade, great demand has led to excess of supply augmented by speculation, producing artificial prosperity, followed by depression and distress. Formerly the suffering followed quick upon and checked and corrected the error: now that those who supply the capital are not

usually they who manage the trade, the corrective is longer resisted, though its operation is finally more severe. This infusion of ill-managed and unproductive capital is one, and by no means the least, of the difficulties introduced of late years into our trade. The prosperity which was at its height in 1872, and which has been succeeded by the existing depression, exaggerated no doubt by hostile tariffs on the Continent and the exclusion of our iron from the United States, illustrates very forcibly the natural sequence which I have attempted to describe.

Although individual manufacturers have been prompt to accommodate themselves to these altered and altering circumstances, they have been slow to form combinations for united action for the common good, and for the acquisition of such general information concerning the progress of the trade as is the concern of all although it can scarcely be acquired singly. In fact, the manufacture has far outstripped what may be called the commercial and legislative divisions of the trade. We are somewhat behind hand in the collection and publication of its statistics, especially those of wrought iron and steel, and we are also far from precision in the returns of the value and character of our iron ores. So also with regard to the freight and general statistics of the conveyance by rail of iron and steel making materials. All inland, and, indeed, all ironwork, are more or less dependent upon railways for the conveyance of their finished iron, of much of their raw material, and often of their fuel, and information as to rates and speed of transit is very important, and should be known to the whole trade. So also with foreign tariffs and treaties with foreign States. The very existence of England as a power of the first-class, if not as an independent power at all, depends upon her being able to hold her own in the manufacturing world, and especially in the manufacturing of iron and steel. Her function for about a century has been to undersell other nations in the markets of the world. Her trade was created by the peculiar skill of her sons, combined with the moderate cheapness of their labor. This led to its expansion, attracting into it a larger capital, giving employment to greater numbers. The original cheapness rested partly on low wages, but the effect of augmented production was to create a larger and ever-growing demand for labor, to raise wages, to diminish the cost of living, and so to improve the condition of the laborer. Recently, however, this production, carried to extreme lengths, has been accompanied by a restriction in foreign markets; and now that nearly every Continental nation, and the United States of America, have decided to foster special native industries by artificial restrictions, it behoves those concerned in the British iron trade to keep a close watch upon commercial treaties and the tariffs of foreign States, to see that the former be acted upon, and the latter grappled with where not absolutely prohibitive.

So also with an equally important subject, Home legislation. Formerly, legislative interference was confined, or nearly so, to the raising of revenue by direct taxation, and there was much intermeddling, usually vexatious, and always mischievous, with the details of manufacture; checking, for example, the manufacture of glass, the making of bricks, the tanning of hides, limiting the admission of light and air into dwellings, indirectly prescribing the form of ships, and so on, supporting a considerable army of smugglers, met by a counter-army of revenue officers, and causing our ports and river mouths to be infested with tide waiters, and thus producing a present revenue at the cost of much crime, to the great discouragement of trade and commerce, and to the checking the operation of that great natural law, by which supply adapts itself to demand, and men are led to buy in the cheapest and sell in the dearest markets, and, in accordance with which, each nation should be left to supply freely that article which it produces at least cost. All this is now swept away, or nearly so, among ourselves. Under the teaching of Adam Smith, and led by Cobden and his disciples, England has discovered that, even in a fiscal point of view, light taxation upon the increased production caused by free trade, best fills the exchequer. Here, in England, at least, we no longer protect special trades at the expense of the general consumer, but rather have we reversed the process,

and, in many cases, we most certainly protect the interest of the many at the cost of the few. For the new system, though, on the whole, very advantageous to the development of trade and manufacture, has been accompanied by a change in the course of legislation that causes to the manufacturer deep anxiety, and demands his continual attention. Modern legislation interferes not so much with things as with persons and classes, and its tendency is in every case to add to the responsibilities and, in the first instance, at any rate, to diminish the profits of the manufacturer. Of legislative measures of this class, the Factory Acts, and the Acts limiting the hours of labor, are well known types, and each year brings into the committee rooms of the legislature a crop of bills almost always well intended, but not always wisely considered. The modern policy springs in the main from good motives, and, carried to a certain extent, has a direct tendency to raise the condition of the working classes, without crippling their means, or injuring the producing power of the country. All interference, however, with the details of a manufacture or the habits of the workpeople, or with the economy of labor, should be accompanied by a degree of knowledge that very few indeed not actually engaged in that manufacture can possess. Not unfrequently the bills brought before the committee contain provisions, which would either be impracticable to work, or, if carried out, would be even more injurious to the class they are intended to protect than to the employer. All legislation of this nature requires to be jealously watched; where sound, promoted; where unsound, vigorously opposed.

Such are the general considerations which have led to the formation of our Association, of which the objects are briefly and conveniently described in the words of our prospectus.

"To secure a means of communication between members of the Iron and Steel trades of Great Britain, upon all matters bearing upon the commercial interests of these industries.

"To procure and circulate detailed statistics of the Iron and Steel trades, both at home and abroad.

"To attend to all matters connected with foreign tariffs, commercial treaties, and Home Parliamentary business, that may have a bearing upon the position of the Iron and Steel trades—excluding questions of wages, or of a purely local character—and generally to take all proper measures for advancing the interests of the British Iron and Steel trades in all their branches."

It is evident that the best way to carry out these aims is by means of an Association. The illustration of the bundle of sticks is as applicable now as it was in the days of Æsop, besides which Associations are not only stronger than individuals, but if well managed they grow stronger as well as wiser as they grow older. This is an age of associations, but although there already exist several, such as the "Federation of Employers," the "United Chambers of Commerce," and the "Mining Association," of a general character, there has no one hitherto been formed specifically to promote the iron trade in its commercial and legislative aspects. With the local iron trade associations, of which there are many, and those excellent, we do not interfere. Such bodies deal with local questions, in which the regulation of wages, and of railway and canal arrangements, form the most important features, and are best left to be so treated. Where these societies touch upon larger, and what may be called imperial questions, we can afford them valuable assistance, since we aspire to promote the interests of the whole trade, and to become on certain classes of subjects, its representative.

But, it has been asked, though it be necsssary for the interests at stake that they should be made the care of a specific association, could not this end have been more conveniently attained by a committee or subordinate branch of the Iron and Steel Institute, already so powerful and so successful? The answer to this suggestion is that the Iron and Steel Institute owes its strength and brilliant condition mainly to the fact that it is busied exclusively with the manufacture, and does not meddle with the trade. It is with technical points only that it is concerned, and it is upon inventions and improvements in the manufacture that it undertakes to disseminate knowledge. Its ordinary meetings afford opportunities for discussions of this character, and it

annually visits one of the great industrial districts of the country, and its members become personally acquainted with such establishments as are best worth attention. Its leading members are all men who, though necessarily more or less conversant with the trade, are mainly celebrated for their knowledge of the details of their manufacture, and for the improvements which many of them, as, for example, Bessemer, Bell, Siemens, and Menelaus, have introduced into it. It is the powerful impulse given by the Iron and Steel Institute which has forced upon us the knowledge that it is not upon the manufacture alone that the success of our business is dependent. The more perfect our processes, the greater our economy of production, the more keenly are we made to feel that our business has another and not less important side, a political and commercial no less than a material economy; and it is by following the example of the Iron and Steel Institute and confining our attention strictly to our own classes of subjects that we can alone hope to rival that body in its success. It may also be remarked that, although the leading ironmasters are concerned necessarily with both branches of their business, and would be as much at home here as in the meetings of the Institute, there are many persons engaged in the trade whose experience and position give great weight to their opinions, but who, taking no part in the manufacture, and excluded therefore to some extent from the discussions of the Institute, will find an appropriate and very useful sphere of action with us. For these reasons, it has been decided to commit the commercial and legislative interests of the trade to an independent society, and it should be the care of those who are members of both bodies to promote that unity of action and cordial concord between them which it is for the interest of the whole trade should be preserved.

And, first, as to the statistics of the trade. "Nothing," said a witty statesman, "is so fallacious as figures except facts," and yet it is to facts and figures that we must look for that precise and trustworthy knowledge of the current condition of the iron trade in our own and other countries, which is so needed by each of us for the proper conduct of his business. It is important to know as accurately and as quickly as possible what is doing, or has recently been done, in production or in sale. An accurate and early account of the quantity of iron produced, of its various qualities and forms, with information as to the variation in the stocks held, will enable the manufacturer to form a tolerably correct judgment as to the relation between supply and demand in the trade as a whole, and in its various branches. We want to know, what is the production of each kind of iron in each district, what is the demand for it, whither it goes, how it travels, what it fetches, and, if possible what was its cost of production. And so of steel: it is important that we should know at what rate rails of steel are taking the place of rails of iron; whether steel is displacing iron for other and what purposes, and to what extent; and whether iron rails of a high class are superseding those of a lower class. These are questions very interesting to the manufacturer, but many of which at present can only be answered inaccurately by estimate, if not by guess. With precise knowledge on these and similar points of manufacture and consumption, at home and abroad, coupled with attention to the growth of railways and other large iron consuming works, the ironmaster will be far better able to decide, than at present, whether he should restrict or augment his output, and in what direction the necessary alterations should be made.

So also of the materials employed in iron making. We should have information from our own and if possible from all iron making countries, whence and in what quantities, of what quality, and at what price, are derived the ores employed. These, and the like statistics, collected, some by foreign governments, some by our own, and some by private associations, some given voluntarily, some by compulsion, and some not, as yet, given at all, we propose to collect and collate, and as far as possible to supply what is deficient. At this time it is impossible to deny that that immense division of British industry, known as the iron rail trade, is slipping out of our hands. From some reason or reasons, the iron rail trade, recently so large, has shrunk to nothing. It is true that no

amount of statistics would have prevented this, but I think that we ought to have had, and might have had, the means to foresee and provide for this change earlier, and far more effectively than we have done.

The branch of science known as statistics, is of modern growth, and is in some degree the business of the state, that is to say, those particulars which can only be obtained by the government, it is the business of the government to collect and make public. Such are the population returns of a country, its vital statistics, the particulars of its finance, its pauperism, its crime, its public burthens, its shipping, its trade and commerce, and in some degree of its agricultural and manufacturing industries. These are matters on which statesmen, those who legislate for a country, need to be informed. Their collection was long neglected by all governments, and has only of late years received much attention from our own. The well-known Northampton tables show in a very striking way the mischief of this neglect. They were collected in the latter part of the last century by private persons, and being, on that accouut, drawn from a limited number of observations, gave an erroneous average of the duration of human life, so that for many years the rate of assurance was unnecessarily high, and the enjoyment of this, the most beneficent gift of statistics to mankind, and one of which England is the parent, was seriously retarded. Since 1834 statistics have been under the protection of a very valuable Society, and we have from the Government minute and accurate returns of trade and commerce, of the circulation, crime, pauperism, and more recently of the mining and metallic operations in the whole kingdom. As regards our own manufacture, its statistics are placed under the Geological Survey Department of the Government, and, as this is a subject that concerns us deeply, I must ask your attention while I enter upon it at some length.

In 1838 the Council of the British Association for the advancement of science passed a resolution strongly urging upon the Government the collection and preservation of the mining records of the kingdom. The result was that in 1840 the "Mining Record Office" was established and a Keeper appointed. It was not, however, until 1845 that the present Keeper succeeded to the office, and his first care was to collect and publish mineral returns. These returns were purely voluntary, and as the Government made no specific provision for their publication they saw the light in an indirect form, first in the memories of the Geological Survey, and afterwards in the records of the School of Mines. These returns, however, were confined to copper, tin, lead, and silver, and did not include iron or coal.

In 1853 the subject was again pressed upon the Government, and since that time the mineral statistics of the kingdom have formed an annual volume that has gradually become more and more complete, and now forms a most creditable and valuable collection. As regards the metalliferous mines, since 1848 these returns have been voluntary. In 1854, the Inspectors of coal mines were directed to give assistance to the Keeper of the Records, and he was allowed traveling expenses, so that he might exercise more influence upon the coal proprietors, whose returns, to his department, were still to be voluntary..

In 1873, the Coal and Metalliferous Mines Acts, 1872, came into operation, and the returns from mines and collieries were made compulsory, but so little was the mining record office regarded that the Acts excluded the Keeper from a right to the use of the Inspector's returns. At this time the metalliferous mines returns are sent to the Keeper by the courtesy of the Home Secretary, but these give the quantity only of the ore raised, and he has still to apply to the proprietors for their money value, without which the returns would be far less useful. The proprietors, who have throughout shown much courtesy, naturally complain of having to make double returns where a single set ought to be sufficient; but having attended to Mr. Hunt's requests for 28 years, they do not refuse compliance, though certainly they ought to be relieved.

The returns now published by the Keeper in his annual volume, show, as regard iron: the blast furnaces built in the year, blast furnaces in blast, annual make of pig iron in each district, and the coal consumed for all purposes in its

production. As to wrought iron, they show the number of mills and forges, the coal consumed in them for all purposes, the number and capacity of the Bessemer converters, and the particulars of about half the tin-plate works. They show also, in raw material, the particulars of ore raised in each mine and in each county, its general description, its quantity, and its value : also the burnt ore from pyrites and other foreign ores imported, together with large, though not complete, particulars as to ore conveyed by coasting, vessels, by canal, and by rail.

In France, Belgium, and Prussia, the returns are compulsory, and are made to and published by the Government. They are of the same general character with our own, in some respects more, in others less, complete.

Now, although our returns are not by any means perfect, they are very valuable, and it is a creditable fact that they are all given voluntarily, and Mr. Hunt, who may be said to have created the department as it now exists, and by whom the annual volumes have been compiled from their commencement, does not wish it to be otherwise. He is of opinion that, with proper arrangements, all that is obtained by foreign governments by compulsion, might be obtained here, quite as fully and correctly, by free will. But for such work the present establishment is insufficient. I have taken the pains to inquire into its particulars, and I find that for a Keeper and two assistants, traveling expenses, and expenses of collecting records, the Government allows less than the salary of a senior colliery inspector. With the practice of the department in seeking information, most of us are familiar. It is simple. Circulars are addressed to the several manufacturers, with schedules which they are invited to fill up. Most do so at once. To those who neglect to supply the information sought, the Keeper makes a personal application. It is seldom that he has to take this step, and very rarely indeed that he takes it in vain.

This subject of the Mining Record Office is one that the Iron Trade Association should at once take up, nor could they well find a stronger case. There are certainly no statistics published by the Government that more affect any of the great industrial interests, none which, so far as they go, are more useful, none which require so little addition to render them complete. I think, too, that it may be said that no department is more economically worked, or, with the narrow means at its disposal, has produced more valuable results. The defects in the returns are the fault of the Government, or rather of successive Governments, with whom statistics have never been popular, and who have not as yet afforded the necessary staff for their collection, and, what is of equal importance, for their rapid arrangement and publication. I may also remark with much satisfaction that by a happy coincidence the same statesman who, in 1853, was at the Treasury, and whose report then made caused the Mining Office to be placed on an improved footing, I mean Sir Stafford Northcote, is now Chancellor of the Exchequer, and may fairly be expected to regard with favor the past success and proposed completion of his work. It may be thought I have dealt too strongly and at too great length upon the importance of statistical details to the individual masters, but in truth it would be difficult to over-rate their value. We want them complete and we want them early, and if the Association does its duty we shall soon obtain them.

I have pointed out briefly what is done in this matter by the governments of the Continent, but we have more to learn therein from the United States, where, as here, the reports are voluntary. The American Iron and Steel Association, in some form or other, has existed twenty years. The current report for 1874 was published in February 1875, and that for 1875 is probably now on its way to England. These reports, though of moderate size, are far beyond anything of the kind published in this country. The volume for 1874, for example, gives an account of the iron trade of the world, showing its fluctuations and their direction, their extent, and the range of its quantities and prices. The report further shows how far such fluctuations are affected by the laws of each country, where legislation is thought to be unwise, and how it should be corrected. There are tables of foreign commerce and of domestic production of the various kinds of iron showing the quantities produced in each of the twenty-five iron-

making States, of pig, of rails, whether iron or steel, and their prices, with the mileage of new railways. Also, a sketch is given of the iron shipbuilding trade; of great works, as bridges, in iron; of the rising make of Bessemer steel and that by other processes; of the production of rolled iron generally, and of the supply of iron ore. Besides these and other domestic topics, the report contains an excellent paper on the relations of capital and labor in the States. The domestic statistics form an appendage to the general report. We may indeed lament that throughout these volumes a narrow and exclusive system of protection is advocated, but we shall do wisely to take example from the energy and general intelligence displayed by the American Association, and shall do well if we are able to rival them in the value and completeness of the information which we may from time to time bring forward. It should also be borne in mind that the American statistics are not only, like our own, given voluntarily, but are collected by the Association, not by the Government.

France also contains a representative iron association, the transactions of which appear periodically as the *Bulletin du Comitê des Forges*, a very valuable publication, very full of facts and statistics of the French trade, both internal and with other countries, and in some respects, more full than the returns from England or the States. There are also associations of a like character in Belgium, Prussia proper, Westphalia, and the Rhenish Provinces, in full activity and of various degrees of merit, the proceedings of which deserve to be better known in England, and will, no doubt, become so by means of this Association.

But, however copious and accurate may be the statistics we may obtain and circulate, the mere collection and publication is but a part of what is wanted. These figures are the raw material which it would be our business to smelt and refine. We must use them as means to an end, and upon the manner in which they are handled and the soundness of the conclusions drawn from them, will depend, in a large measure, the usefulness and character of our body.

Next have to be considered the commercial and legislative conditions of the iron trade, two points very closely connected, not, indeed, naturally, but because questions of commercial treaties and foreign tariffs, as well as of home legislation are usually approached through the Government and through Parliament.

The general policy of the leading countries of Europe and of the United States leans strongly towards protection, and the effect, in the iron trade, has been in a great measure to shut out British iron from France, Belgium, Germany, and the States, and Russia seems following in the same track. In each country, specific interests outweigh the general good, and the profits of each trade are enhanced at the expense of the public. No combination of Englishmen can at once work a change. England could indeed exclude, as formerly, French wines and manufactures, and Russian hemp and tallow, but to do this would be to commit the very error of which we complain, to punish our masses for the advantage of certain specific trades, and to depart from that practice of free trade which Adam Smith regarded as too Eutopian a blessing ever to be enjoyed among men, and of which England stands nearly alone as the apostle. But if we cannot at once lead foreign nations to follow our example, and can only trust to time and the diffusion of knowledge to bring about the change, still we need not altogether despair. In our own country it was only by the steady exertions of a small but active minority that the change was brought about, and both in France and the States exists a strong and probably an increasing party in favor of free trade, in conjunction with which we may do something to enforce the observance of existing treaties, and watch over their renewal. Something may also be gained by the obtaining accurate information as to what form of iron can be exported at a gain, so as in some degree to turn the flank of a hostile tariff if we cannot meet it in front. And so as regards the importation of raw material from the Continent. You are aware that at this time English capital has been largely invested in Spain in opening iron mines and in forming communications with the port of Bilbao, and that the Spanish Government, if Government it can be called, has taken occasion, when

that quarter of the country is convulsed by insurrection, to lay an export duty on a trade which they ought, for their own sake, to encourage by every means in their power. To this impost our Association should have something to say, both before our foreign minister and at Madrid.

In home legislation we may hope to effect much more. Each year brings before the Committees of Parliament, bills bearing directly or indirectly on the iron trade, and often pushed forward by the trades' unions and by the force of public opinion, which, when ignorant of the circumstances, is commonly against the manufacturer. Our Association, strong in its representation of a great and wealthy trade, and in the accurate knowledge concerning that trade possessed by our leading members, should sit in council upon each projected measure, weigh well its provisions, and, while accepting in good faith those social improvements which are the object of what has been called Factory Legislation, take care that these be effected with as little interference as possible with the details of the manufacture and the habits of the workpeople. If we are guided by a desire, not to secure temporary profits, but to advocate what may be best for employer and employed, whose interests, often, temporarily or apparently, at variance, are yet in the main identical, we shall win the respect of the working classes and the confidence of the trade, be listened to by the Legislature, and be in a fair way to fulfill the hopes of the founders of our society.

There is yet another branch of public business, allied to the former, which comes within our scope. It will be for us not only to endeavor to influence our law makers, but to have something to say to the administration of the laws regarding our trade when made. Formerly, when a law was passed, it was in most cases left to be called into action by those whom it concerned, and an informer was stimulated to bring it into operation by the prospect of a share in the penalty inflicted, if a fine. The modern system is different. Many of the laws passed on behalf of the working classes are obnoxious to, or at best disregarded by, those whom they are intended to benefit, and to secure the application of such laws, the Secretaries of State and the Committees of the Privy Council and other Government departments are invested with almost despotic power, put in action through a cloud of inspectors amenable only to the central authority. Our schools, poorhouses, cottages, workshops, collieries, engine houses, are all under inspection. Hours of work, public clocks, sewers, water supply, rubbish heaps, water-courses, are all visited by men who exercise inquisitorial functions, and who, though usually chosen with care and some regard for their fitness, are, at the least in the earlier part of their career, more distinguished for zeal than for experience. This system, probably on the whole good, and to some extent absolutely necessary, is very liable to abuse, and needs to be very carefully watched, so that what is objectionable may be removed or amended.

There is a close and an increasing connection between the iron trade and the railways of the country, not only as regards the manufacture of the rails, but as regards the conveyance upon them of ore, fuel, and iron. To the introduction of railways is due the great development of the iron trade, and it is the continued demand for railway iron that has raised and maintained this trade as one of the great industries of the world. Where other customers have taken from us scores and hundreds of tons, railways have taken tens of thousands, and to them it is mainly due that, in the thirty years following their introduction, our make of malleable iron quintupled. Nor is it only as customers that railways have benefited our trade. By the facilities they afford we are enabled to draw our ironmaking materials from sources that would otherwise have been closed. Forty or even thirty years ago, the convenient conjunction of iron ore, coal, and limestone, was the cause of the prosperity of some of the most important seats of the manufacture. This is no longer the case to anything like the same extent. By the rail we can transport the coke of Durham at a cheap rate to the Cleveland iron stone, and the same admirable fuel across England to the rich hematites of Barrow. It is not too much to say that, but for the facilities of transit afforded by railways, the progress of Middlesbrough must have been

slow, and Barrow could scarcely have existed at all as a great centre of the manufacture of iron and steel.

But, much as we owe to railways and the railway system, and good customers as we and our brothers of the coal trade are to them, our interests are by no means identical at all points, though our alliance need not be the less cordial that it requires careful and constant watching. Railway managers are a very able and a very quick-witted class of men, and though generally aware, and ready to admit in the abstract, that the safest profits are those derived from low rates and great facilities for transport, they sometimes are found to sacrifice these broad and well-formed views for present gain. It is true that the ultimate object of a railway manager is the giving a good dividend to his share-holders, and not the development of the resources of a district, but what we have to keep steadily and powerfully before these gentlemen is the fact that these two points are in the main inseparable, and that, not only where the resources of a district are large, but even where they are but moderate, it is sound policy, even at a present loss, or with a very moderate margin of profit, to induce their development. Sam Slick's plan with his clocks was a very good one. Lend your clocks freely and after a short time people find they can't do without them and will purchase. Once let a railway be at work and the interests which it generates become too strong to be allowed to drop. Many of us know cases in which a single railway has held the monopoly of a district and checked its progress, as proved by the vast increase of trade which has followed upon the opening of rival lines.

This subject of facilities of transit is one to which the attention of our association should be directed, and the just and wise regulation of which we should promote with such influence as we may possess. As the margin of our profit becomes less, so much the more important does it become, that we should have cheap and convenient facilities for the transit of our raw material and our finished or half finished produce, nor are there any two points in England so distant that a profitable trade might not be made to spring up between them by a liberal railway policy, or, what is even more important, the trade between which might not be diverted or even destroyed by one of a short-sighted character. When I state that in stirring times the pig iron of Middlesbrough is actually brought by rail to South Wales, I adduce a very strong argument in favor of cheap transit, and show how extreme a case is made possible under a liberal railway policy. To obtain and maintain the exercise of such a policy, no exertions on our part should be wanting.

We have proposed, and I think wisely, to exclude from the scope of our association "questions affecting the regulation of wages or those of a local character." These are best left to the consideration of the associations now to be found in every manufacturing district. For their equitable adjustment they require a close knowledge of circumstances, and are besides accompanied too often by irritations and heartburnings and mutual animosities, which it is very undesirable to import into our discussions. But it by no means follows that the philosophy of wages, and the distribution of returns between labor and capital are not to be considered here, as well as those questions of interference with natural laws and individual freedom of action which are connected with fluctuations in the price of labor, and with the general relations between the employer and employed. For such questions lie at the root of our own and every other trade. Upon their solution rests the prosperity, not only of our trade or of our country, but of the whole world ; and the statistics of production, commercial treaties and tariffs, and home legislation, important as such subjects are, sink almost into insignificance before that one great question of the wages of labor.

Labor and capital, which is the accumulation of labor, are co-equal powers. Without labor, capital yields no return, and will be dissipated : without capital, labor cannot be employed to advantage, and the laborer cannot rise to independence. Unfortunately, this truth, which is as fixed and indestructible as any other of the laws by which the world is governed, has not yet forced its way into the understandings of the masses in this or any other country. If it be too much to say that labor in England, as in the

centres of manufacture in France, has declared war against capital, it is at least that it places itself in opposition to capital, and the employer, who but recently was regarded as a useful citizen, is now, to some extent, thought to be one who desires to reap where he has not sown, or at the best claims more of the joint produce than he ought to do. The causes of this change are deep-seated. During the last half century, since the end of the wars of the first Napoleon, there has arisen all over Europe and in the United States a great development of the industrial arts, fostered by the general use of steam power, by vast improvements in machinery, by the tendency of such machinery to create large establishments and augment already over grown towns, by the construction of railways and steamboats, by immense facilities in postal communications, by the removal of the tax on newspapers, and, finally, by the invention of the electric telegraph. The effect of all this has been a rise in the wages of labor, not nominal only, such as might be produced by the greater plenty of the precious metals, but real—great and rapid beyond anything before experienced, and raising, in every article into the production of which labor at all largely enters, the cost of production in a far higher proportion than that of the necessaries of life, though most of these have also risen, and considerably. During that long period from the commencement of the reign of Louis XIV. to the battle of Waterloo, while other nations were distracted from the arts of peace by war or the apprehension of war, England, from her insular position, was at rest, and became gradually a hive of successful industry. During the latter part of that time she was supreme in the markets of the world for manufactured goods. The English capitalist took the lead in boldness of adventure; the English artisan in skill and perseverance. "Indocilis pauperiem pati," the device of the merchant venturers of one of our great seaports, was the sentiment of the whole nation. In the employment of her coal, the construction of her machinery, the outlay of her capital, the industry of her artisans, and the force and energy of her marine, England had no co-rival. "Wherever," said Napoleon, with the bitterness of deadly hate and envy, "wherever a cockboat can float, there I find the British flag," and beneath that flag were poured forth the cotton and the cutlery of Britain.

But the fall of Napoleon, and the repose that followed, enabled other nations to come forward in the race, and whatever may have been the continued progress of England, and it was great, France, Belgium, Germany, and the United States, gained greatly upon her, though even as lately as the introduction of railways on the Continent, Mr. Brassey could testify that, although English wages were higher than in any other country, railway works could be executed more cheaply by English than by any other labor.

There arose in England a belief, and a not ill-founded belief, on the part of the artisan, that he obtained too small a share of the returns to which, by his industry, he had largely contributed, and for this larger share, as for all good things in this world, he had to contend. At first, in the ignorance in which the working classes had culpably been suffered to remain, they had recourse to riots and open violence, but by degrees, better instructed, they formed the combinations known as trades unions, organized at first as provident or benefit societies for the sick or aged, afterwards extended to take in hand the regulation of wages and particulars of labor, and, from time to time, with perhaps equal excuse, but with less wisdom, employed also in political questions.

Our immediate and direct business as British manufacturers, is with British unions; but as these combinations exist in extreme forms elsewhere, our Association will have also to pay attention to the fruits which they produce in other countries.

Now combinations on the part of the artisan classes and in their interest are natural and right, and, since the alteration of the law in 1824, are legal. Although capital and labor are so intimately connected that one cannot be deeply injured without injury to the other, they have also points of variance, and it is only by a conflict of forces that a resultant course, representing each, can be arrived at. What has to be secured in these struggles, in the interests of the

whole community, is that neither party interfere with that entire freedoom to employ himself at pleasure in any lawful trade, which is the ancient right of every man under the common law of England, and which, though from time to time hampered by statute, was never lost, and is now once more fully recognized by the legislature. Trades' unions being thus in themselves lawful and right, and the recognized organs of labor, it becomes essential that their course of action should be understood, and this must be gathered not so much from their professions, though these are not indistinct, as from their practice. Their first and main, and very legitimate object, is to increase the wages of labor, and to bring this about by the means, equally legitimate, of combination. But having, by the setting forth so desirable an object, by means so legitimate, obtained the confidence of the artisan classes, they proceed to steps of a different character. To raise wages they adopt means which diminish production, and this by restricting the number of artisans admitted as apprentices into a trade, by shortening the hours of work, by discouraging piece work, and, where possible, the employment of machinery, and it is difficult to say which of these devices is the more opposed to sound principles or to the general interests of the whole commonwealth.

What rent is to land and wages are to labor, profits are to capital, and as they form the residue of the fund of returns out of which, where a trade is successful, wages must ultimately be paid; anything that diminishes that fund has, so far, a tendency to lower wages, and, therefore, whatever means are adopted to obtain for the laborer a larger proportion out of the fund, great care should be taken that they are not such as to diminish its total amount. But profits depend for their rate upon the cost, not upon the wages, of labor, and the cost of labor is determined by the proportion between the wages of the laborer and tha value of his production; consequently, measures that have a direct tendency to diminish the quantity of an article produced and to raise its cost, will, so far, depress the trade in favor of rivals who are allowed more freedom of action, and so will work injury to all. To restrict by artificial means the number who may follow any particular trade is only to throw upon the mass a number of persons who might be better employed, and who, by adding to the general supply, have a direct tendency, to lower the average of wages.

Profit, or that which remains to the employer when his capital is replaced and the wages of labor have been paid, is the joint produce of capital, skill, and industry, but it is an error to represent it, as is now often done, as the fruit of industry alone, and therefore the property of the workman; nor is the step from this a great one to that of representing the interest of the employer as altogether opposed to those of the employed, and seeking to compel him to raise wages with but little regard to the source whence alone they can be derived.

As to the hours of labor, it may be admitted that in some trades they have been too long for the average workman, and so far as they tend to depress him physically and intellectually were therefore injurious to the community. Relief on this head was no doubt needed, but to forbid any man, whatever may be his strength or skill, to employ those qualities for his special benefit was scarcely the way to bring it about. The tendency of such an order is to place the weak and strong, the skillful and the unskillful, the idle and industrious, on the same dead level. It is true that in practice the Unions do not carry their opposition to piece-work to the length of absolutely prohibiting it, but the arguments employed by them, if followed to their legitimate consequences, would be prohibitory The manner in which these restrictions have been enforced, is equally objectionable with the restrictions themselves, and includes all methods of coercion from social exclusion up to serious bodily injury and even death. All individual liberty is forbidden. The conditions of labor are dictated by a committee of delegates whose deliberations are, not unfrequently, kept secret, and whose authority is paramount.

It may be said, probably with truth, that the regulations of the Manchester and Sheffield Unions, conceived in ignorance and enforced by crime, are confined to unions composed of the lowest and most ignorant class of workmen, and are disapproved of by all others. Still,

admitting this to the full, the violation of sound economy and the interference with individual liberty are rather in degree than in principle.

Of course it often happens that a Union is not strong enough to carry out its wishes to their full extent, but their tendency is such as I describe. Even if the restrictions were in themselves in some respects beneficial, they are not the less an interference with that individual freedom for which we in England have struggled so long; and their direct effect is to lower the standard of excellence attained by British industry, to deteriorate quality, to check quantity, and to enhance cost, and to do this by forbidding individual freedom of action, and diverting the natural course of labor into artificial channels. It is scarcely for a Government, still less for an irresponsible and private body, to judge what trades are overcrowded. That this and similar points are best left to be settled by natural laws is a truth which we in this country have been slow to learn, but which we have learned, and will, I trust, yet maintain.

Moreover, this system of interference with natural law, supported by petty annoyances, rising to social terrorism, is even now producing its effects in England by the stimulus it affords to the productions of other countries. Belgium already runs England very close in all her great industries. Wages in that country are far lower than here, and the cost of living is about the same.

Her artisans are skillful and industrious, and her progress has been effected during a period when her very existence as an independent nation was threatened.

There is the less excuse for this suicidal policy that not only in Belgium but in France and Germany, wages are lower and the position of the artisan less advantageous than with us. Here there exist few or none of those old legal restrictions on trade that linger in parts of the Continent, and especially in Germany, and which are described as having been, in the United States, at at the close of the late war, far more vexatious than those prevailing in England in the days of Mr. Pitt, and the contemplation of which drove Mr. Wells to become a freetrader. In England, food, clothing and lodging, are as cheap or cheaper than on the Continent, and the industrious, prudent and skilled workman can at this time do better for himself here than even in the United States. The Consular returns to the Foreign Office, first called for by Lord Clarendon in 1869, returns which might be consulted with advantage by our working classes, show that in no country, excepting perhaps Holland and Switzerland, is an artisan better off than in England, and in Switzerland the difference seems to be due only to their greater frugality and the absence of intemperance.

In these disputes about labor, as in not a few of our national troubles, the cause is mainly ignorance. The English artisan is not usually by any means a vicious man. Even where he joins in attacking employers as a class he not unfrequently bears no sort of malice against his own employer. He does not seek to regenerate his country by bringing every capitalist to the scaffold, or even to the poorhouse, or by destroying public monuments or other evidences of national greatness or accumulated wealth. Where the individual master, and, in some considerable degree, where the masters of a special district are allowed to deal directly with his or their own men, the men are usually willing to listen patiently to reason. Nevertheless, it is vain to disguise or deny the fact that British workmen by their representatives the trades' unions, are at this time acting in opposition to the doctrines of free trade and of freedom of action.

The drift of the Western world, ever since the invention of printing, has been all in one direction, and every movement has contributed to improve the condition of the mssses. Privilege after privilege, restriction after restriction, has crumbled away. The discovery of America, the doubling of the Cape of Good Hope, the use of gunpowder, the reformation in religion, the colonization of the fifth division of the globe, every discovery, every invention, has been a step in the same direction, tending powerfully to equalize social conditions, to break down divisions, to bring about, not that equality of individuals which is the empty but dangerous dream of the socialist, but the removal of artificial restrictions,

and to allow each man freedom to employ his powers in that way which seems to him the best, and which has been found to be on the whole the best for the community.

But a few years ago, the policy of protection was almost an integral part of our industrial system, in manufactures, commerce and agriculture. And yet in England, a country very distrustful of change, as change the voice of reason has been heard, and great and powerful interests, such as those involved in the navigation laws, and the growth of corn, have given way. It has only been after severe struggles, and at great cost to many specific interests, that perfect freedom of manufacture and of trade, and individual freedom of action, have been won and established, and we are now asked in the interests of labor to reverse this decision, and to return to a system of restrictions and interferences, which is at direct variance with all our convictions.

I have touched at some length upon these burning topics, I hope in no spirit of cavil or exaggeration. I have described the operation of Trades Unions, as they are now, or have recently been, carried on, and especially as they affect the iron, and its subsidiary, the coal trade, and this I have done because, although it is highly undesirable that this Association should become an arena of controversy, it cannot but be that we shall have to give our attention, and our most serious and anxious attention too, to one of the most complex and most pressing problems of modern times, and one upon the solution of which depends the prosperity of our own trade, and, in a great measure, that of our own country.

Our Association enters upon its existence in a time of general depression, and one in which we have to grapple with new and somewhat formidable dangers. But the qualities which have gained will maintain success, and they know but little of England, who suppose that the energy and boldness of our capitalists, or the skill and industry of our working classes have seriously fallen of, or that our internal disputes will not be conducted, on the whole, with that practical sense and moderation to which we, as a nation, lay claim. Even now, dark as is the hour, and deep the winter of our discontent, there are not wanting symptoms of a revival, nor, perhaps, is it too much to express a hope that we may soon be able to hail with the poet, as a sign of the returning spring, that

'Vulcanus ardens urit officinas.'

and may see

"The silent furnace once again in blast."

ON THE EXPANSION OF SEA-WATER BY HEAT.

By T. E. THORPE, Ph. D., and A. W. RUCKER, M. A.

Proceedings of the Royal Society.

The extensive contributions which have recently been made to the physical history of the ocean have shown the desirability of exact knowledge of the relations of sea-water to heat. We have accordingly thought it worth while to make observations in order to determine the law of the thermal expansion of sea-water.

The only attempt hitherto made to solve this problem which can lay any real claim to consideration is due to the late Professor Hubbard, of the United States National Observatory. The results of his investigation are contained in Maury's "Sailing Directions," 1858, vol. i. p. 237.

Muncke, nearly fifty years ago, determined the expansion of an artificial sea-water at various temperatures between 0° and 100°C.; but our confidence in the results as applicable to natural sea-water is affected by the circumstance that the solution was prepared from data furnished by the imperfect analyses of Vogel and Bouillon La Grange.

The observations of Despretz were confined to temperatures below 13°.27, as the main object of his inquiry was the determination of the point of maxi-

mum density of sea-water. The subsequent investigations of Neumann and Rossetti were equally limited, as they were undertaken with the same view.

The water used in our observations was collected from the Atlantic, in lat. 50° 48′ N. and long. 31° 14′ W.; and its specific gravity at 0° C., compared with distilled water at the same temperature, was found by the bottle to be 1.02867.

The method of experiment was precisely the same as that already employed by one of us in determining the expansion of the liquid chlorides of phosphorus. It was essentially that already used by Kopp and Pierre ; *i. e.* the expansion was observed in thermometer-shaped vessels (so-called dilatometers), graduated and accurately calibrated.

Three of these instruments and two sets of thermometers were employed. The latter were made by Casella ; the length of a degree in different instruments varied between 9 and 13 millims.; they had been compared (the one set directly, the other indirectly) with Kew Standards.

Three perfectly independent sets of observations were made with the water in the state in which it was collected ; and as Mr. Buchanan, of H. M. S. 'Challenger,' has found that the specific gravities of different sea-waters lie between the extreme values 1.0278 and 1.0240, and since, in order to be of value in the investigation of the physical condition of the ocean, the observations on their values and the formulæ of reduction ought to be correct to the fourth decimal place, we diluted quantities of our sea-water with distilled water, so as to have specimens of approximately the specific gravities of 1.020 and 1.025 ; and we concentrated a third quantity by evaporation until its specific gravity was increased to 1.033, and made two series of independent observations on the expansion of each solution.

As we wished to confine ourselves to circumstances to which sea-water is naturally exposed, we did not carry on our experiments at temperatures higher than 40° C.

Empirical formulæ were calculated to express the results of each series of observations ; and in the original paper full details of the observations are given, together with Tables showing the agreement between the calculated and observed results, and also (after the necessary corrections and reductions have been made) between the volumes calculated from the formulæ from different series of observations on the same solutions.

Finally, a general formula of the form

$$v = \Phi(t) + \chi(t) f(s)$$

was found, giving the relation between the volume (v), temperature (t), and specific gravity at 0° C. (s) of any solution of the same composition of sea-water the specific gravity of which at 0° C. lies between 1.020 and 1.033, the volume at the same temperature being taken as unity ; in which expression

$$\Phi(t) = 1 + .00008097\,t + .0000049036\,t^2 - .000000012289\,t^3.$$

$$\chi(t) = -10^{-5}(.5509\,t - .020198\,t^2 - .00033276\,t^3),$$

and

$$f(s) = 11.95 - 940\,(s - 1.02).*$$

In the original paper we show that if Σ be the specific gravity at any temperature t of a solution the specific gravity of which at 0° C. is s, we may without sensible error assume $\frac{d\Sigma}{ds}$ to be constant; whence, by means of the above formula, we are able to give in the following Table all the data necessary for calculating the specific gravity of sea-water of any degree of salinity at any temperature between 0° and 36°. Column II. contains the specific gravities at the temperatures given in Column I. of a solution the specific gravity of which at 0° C. is 1.02000 ; Col. III. contains the numbers which must be subtracted from those in Column I. for each increase of 0°.1 over the temperatures opposite to which they are placed ; and Column IV. the numbers which must be added for each increase of .00001 of the specific gravity of the solutions at zero. At the heads of Columns III. and IV. are the numbers of ciphers which must be prefixed to the figures written in them in the unit place.

* The numerical constants involved in the above formula are given in the forms in which they were, for facility of calculation, determined. The expression can of course be easily transformed to the simpler form, $v = F_1(t) + s\,F_2(t)$.

Temperature.	Specific gravity.	Proportional parts for 1° C.	Proportional parts for .00001 increase in spec. grav.	Temperature.	Specific gravity.	Proportional parts for 1° C.	Proportional parts for .00001 increase in spec. grav.
°		.0000	.0000	°		.0000	.0000
0	1.02000	3	1	19	1.01740	25	0 944
1	1.01997	4	0.995	20	1.01715	25	0.943
2	1.01993	5	0.990	21	1.01690	26	0.941
3	1.01988	6	0.986	22	1.01664	27	0.940
4	1.01982	8	0.932	23	1.01637	28	0.938
5	1.01974	9	0.879	24	1.01609	29	0.937
6	1.01965	11	0.975	25	1.01580	29	0.935
7	1.01954	12	0 972	26	1.01551	30	0.934
8	1.01942	13	0.969	27	1.01521	30	0.932
9	1 01929	14	0.966	28	1.01491	31	0.930
10	1.01915	15	0.963	29	1.01460	32	0.928
11	1.01900	17	0.961	30	1.01428	32	0.925
12	1.01883	17	0.958	31	1.01396	32	0.922
13	1.01866	19	0.956	32	1.01364	33	0.919
14	1.01847	20	0.954	33	1.01331	33	0.915
15	1.01827	21	0.952	34	1.01298	33	0.912
16	1.01806	21	0.950	35	1.01265	34	0.908
17	1.01785	22	0.948	36	1.01231	34	0.903
18	1.01763	23	0.946				

In order to facilitate the use of the Table, we subjoin directions for its application in the form of rules, and give a couple of examples :

I. Given the specific gravity of a sample of sea-water at any temperature t, to find it at 0° C.:—Look out in Column I. the figure giving the number of entire degrees of the temperature ; multiply the corresponding number in III. by the fraction by which the observed temperature exceeds that number, and subtract the results from the corresponding number in Column II. Subtract the difference from the observed specific gravity, and divide the number so obtained by that corresponding to the observed temperature in Column IV. without prefixing the ciphers at the top of the column) ; add the quotient to 1.02000, and the sum will be the specific gravity required.

Example I. Specific gravity observed at 18°.5 C.=1.02475. Number opposite 18 in Column. III. is .00023, which multiplied by .5 equals .00011 ; and

$$1.01763-.00011=1.01752.$$

Subtract this from the observed specific gravity,

$$1.02475-1.01752=.00723.$$

Divide by .945 (the number corresponding to 18.5), and the quotient is .00765, which added to 1.02000 gives 1.02765 as the specific gravity at 0°. C.

Example II. Specific gravity observed at 15° C. = 1.02570.

$$1.02570-1.01827=.00743,$$

and

$$\frac{.00743}{.952}=.00780.$$

Therefore specific gravity at 0° C. = 1.02780.

We next discuss the discrepancies which occur between our own results and those of Professor Hubbard ; and we point out various circumstances in the methods employed in making and reducing the latter observations which appear to us to explain in a great measure the divergences which exist.

A PROPOSAL is to be laid before the Austro-Hungarian delegations for facilitating the navigation of the "Iron Gate" on the Danube. The works will, it is estimated, cost about 6,000,000fl., and it is proposed to recover this amount by levying toll on all vessels that pass. The other Danubian States, viz., Turkey, Servia and Roumania, have already expressed their entire concurrence in the project.

ON THE COMPARATIVE MERIT OF SIMPLE AND COMPOUND ENGINES.

By G. B. RENNIE, Esq., M. Inst. C. E.

"Journal of the Royal United Service Institution."

Having been invited by the Council of this Institution to read a paper "On the comparative merit of simple and compound engines," I will endeavor to lay my views before you with as few technical expressions as possible. That such a subject cannot be treated altogether free of such terms, and as I expect that several members present here to-night are of the Navy, who have mostly a knowledge of the construction and management of the propelling machine on board a man-of-war, I trust your indulgence in allowing me the use of a few professional words.

It will *first* be advisable to understand what is meant by the terms simple and compound engines (those being the words given by your Secretary). As regards the "simple engine," it may be either taken as the simplest type of steam engine in ordinary use, such as with a single cylinder, without separate appliances for "cutting off" the steam to allow it to expand more than is due to the ordinary "cut off" made by the slide valve, and to discharge the steam so used direct into the atmosphere; or it may be considered an improved form where the steam is expanded to its utmost by the use of separate expansion-valves, or by utilizing the steam discharged by heating the feed water, or improving the draught of air in the furnace, by turning the discharged steam into the chimney by what is known as the "blast," or by condensing the discharged steam either by direct contact with cold water, or what is known as surface condensation, and finally taking advantage of the steam so condensed in creating a vacuum by the application of an air-pump to discharge the air and condensed steam. Though all these forms of engine, each of which is a gradual improvement on the efficiency of the machine, may be taken as the "simple" marine engine, yet I am inclined to think the latter, which may be considered as the most improved type of using the steam advantageously in a single cylinder, so as to get the greatest power out of a given quantity of evaporated water, is what would be most interesting to you to form a comparison with what is called the "compound" engine.

Secondly. The compound engine, in contradistinction to the ordinary or simple engine, has two or even more cylinders for using the same steam, that is, after the steam has done its duty in one cylinder, it is discharged into another, and in some few cases again into another, until the maximum effect is obtained out of the steam by its expansion.

The usual form of compound engine is to have only two cylinders in a complete machine, the two cranks being placed at right angles with each other, as with the "simple engine," but they are not unfrequently made with four cylinders, viz., one large and one small to each crank. The proportion of the large to the small cylinders in either system depends on the steam pressure used, the amount of its expansion, and whether especial mechanical arrangements are made for cutting off the steam by independent valves, or merely allowing the steam to expand, according to the relative volume of the two cylinders. The usual proportion is, however, three or four to one.

Examples of the first arrangement are the "Briton" and "Tenedos," similar ships of 350 nominal horse-power. The results of the trials of these two ships may be said to have commenced, the compound system being adopted in the Navy, though the "Sirius" and "Spartan," of similar horses' power, had been tried some time previously. These two are of the second type of compound engine above described, each crank having a large and a small cylinder working on it.

The results of the "Briton's" trials are published in the "Transactions of the Society of Naval Architects," from a

paper I read at a meeting of the Society held in March, 1871.* The consumption of coal at full power was slightly under 2 lb. per indicated horse-power per hour, the best result being obtained when working about half power, when only $1\frac{1}{3}$ lbs. was burnt per indicated horse-power. A nearly similar result when working full power was obtained with the compound engine for driving the new pumping machinery at Chatham Dockyard. Arrangements were made for measuring all the steam used in the engines by discharging it, after it was condensed into water, into two tanks. The power by the indicator was taken every ten minutes. The total time of working the engines was a little over $3\frac{1}{2}$ hours, and it was found that 18.92 lbs of water were used in the shape of steam per indicated horse-power per hour; and as the coal used, viz., "Fothergill's Aberdare," has, according to Admiralty experiments, an evaporative power of 9.73 lbs. of water per lb. of coal, this would give (taking the steam used as the basis of calculation) a little under 2 lbs. of coal per indicated horse-power per hour.

I have here a table of the comparative consumption of coal of different kinds of engines. This comparison was made a few years ago, and from further observations I think it is, on the whole, a pretty fair one.†

There may be many engines of each kind which may consume more or less than stated; but supposing them to be all under the same usual conditions, both as to manufacture, kind of coal, and other circumstances, I believe it is not far from correct.

Since this table was made out, I have had a most satisfactory opportunity of comparing the results of the coal consumed between the ordinary or simple injection engine working with 25 lbs. steam in the boilers, and the same engine, after being compounded, working with about 55 lbs. steam in the boilers.

The "Minia," was a screw steamer of 200 nominal horse-power. The cylinders were 54 inches diameter, with a stroke of 3 feet 4 inches. The number of revolutions of the screw propeller was about 60 per minute. The engines were the ordinary overhead construction, with injection condensers and boilers for working with 25 lbs. steam pressure. The

* *Particulars taken from the Reports of the Official Trials of the Compound Engines of H. M. S. "Briton" for six hours' steaming.*

Date of Trial.	Mean speed of ship in knots.	Pressure of steam in engine room.	Revolutions per minute.	Indicated horse-power.	Coal per horse-power per hour.	Time of steaming with 240 tons.
2d June	12.767	51.91	92.649	2,018.3	1.98	$5\frac{1}{2}$ days.
10th June	10.026	50.00	67.308	660.58	1.3	26 days.

† *Comparative Consumption of Coal of different Types of Engines.*

Type of Engine.	Per H. P. per hour.	Tons per diem.	Days and Hours steaming with 240 tons of coal. Days.	Hours.
1. Improved compound	$2\frac{1}{4}$	48	5	0
2. Ordinary type with surface condensers and superheaters	$3\frac{1}{2}$	75	3	4
3. Ordinary injection	$4\frac{1}{2}$	97	2	11
4 High pressure	6	129	1	21

average consumption of coal was at the rate of 33 tons per 24 hours, with a maximum consumption at full power of 45 tons per diem. The engines were "compounded" by my firm, by placing small cylinders of 27 inches diameter on the top of the existing cylinders. A surface condenser was also added, and one of the existing air pumps was converted into a cold water circulating pump. Four new boilers, adapted for 60 lbs. working pressure, were also supplied. The rest of the engine, including the screw-propeller, remained as before, and the result has been that the average consumption at sea has been reduced to 17 tons per diem (equal to about 2¼ per indicated horse-power), with a maximum consumption of 24 tons when working full power, and the revolutions of the screw propeller, and consequent speed of ship, has been slightly increased. That is, the coal consumption has been reduced nearly one-half since the engines have been "compounded."

I may also cite another example of the comparison between the ordinary injection engine and a new compound engine which had been substituted for it. The "Pera," a screw vessel belonging to the Peninsular and Oriental Company, had formerly vertical geared engines of the injection type, which were considered very economical in their day.

The nominal power was 450 horses, and gave an average yearly speed of 10.4 knots per hour, with a consumption of 43 tons per diem. New engines were placed on board, of the compound type, and the ship ran from Brindisi to Alexandria, with the Indian mails, making an average somewhat over 10½ knots, with an average consumption of about 24 tons of coal per diem. This is an example where both engines are by the same makers, with equally good manufacture, and the same engineer management on board, and the ship navigating the same seas.

As an instance what can be done in making a long sea voyage entirely under steam, with a small-sized ship with compound engines, I may mention that of a dredging vessel of 160 feet in length, and 28 feet beam, fitted with twin screws and compound engines of 70 nominal horse-power, having made the voyage from London to Buenos Ayres in 46 days, stopping only once, namely at Madeira, to fill up with coal; that she steamed a distance of about 5,000 miles, between Madeira and Buenos Ayres, in 36 days, without taking in fresh coal. Had the ship had the old class of engines, she would have been obliged to have made the voyage under canvas, or to stop at intermediate ports to take in coal.

It will be understood that such a radical change in the propelling machine of a ship, enabling her to be steamed nearly double the distance with the same weight of fuel, is so important in its effects on ocean steam navigation, that one can hardly be surprised at the demand there has been in the mercantile world for ship engines of the new type; but the increased number of steamers and accelerated trade thereby, so increased the demand for coal, which was not supplied in the same rapid rates as the ships and engines, and so augmented the price of it, that the money equivalent from the reduced amount of coal used in each ship has not been realized to what was expected, and has unfortunately now caused a considerable stagnation in the shipping trade.

The improved result in point of consumption of coal of the compound engine over the old type engine, is not due entirely to making the steam do duty in two cylinders instead of one, but to the different conditions in which the steam is used, viz., to the greater boiler and initial pressure used in the cylinders, and to expanding it to a much greater extent than formerly, in order to get the full duty out of it. The question of the relative advantage of expanding steam in one cylinder or two has been a controverted one with engineers for many years, especially as regards land engines, where the higher pressures had been more frequently used; but I think it is now pretty well agreed on all sides by those who have studied the subject, that where the pressure of steam, amount of expansion of same temperature, and dryness being also alike, and with equally good manufacture and superintendence, that the fuel consumed per indicated horse-power, is practically identical in both systems.*

* That is, when the pistons are of so good a construction as to be practically tight; but should that not be the

We have adopted the compound engines for many years; in 1842 we supplied them for Messrs. Cubitt & Sons, London Dock pumping engines, Royal Arsenal, and many others. The engines on this plan are usually called "double cylinder beam engines," and work with about 60 lbs. in the boilers; our preference for this engine being that the strains were more uniform and less severe, and the rotatory motion more equal. The consumption of coal I find in referring to some old examples, was about 2¼ lbs. per indicated horse-power, or about the same that is realized in a good compound engine.

It is always a difficult matter to get good examples of a fair comparison between two classes of engines, but as regards land engines, I may quote the trials between the simple and compound engines made at the New River Waterworks Company, where, I believe, as far as consumption of coal was concerned, there was practically no difference in the two systems. As regards marine engines, the comparative trials between the "Goshawk" compound and the "Swinger" simple, with two cylinders of equal size, will be in the recollection of many, but it may be well to state the leading particulars. These two vessels were of like tonnage and horse-power, the trials were of six hours' duration, and took place at the same time and place. The average power of the "compound" was 374.2 horses, at a consumption of 2.6 lbs., and the "simple" was 364 horses, at 2.61 lbs. per square inch. After the trials to test the coal were completed, the speed of each vessel was ascertained on the measured mile, which showed the "compound" vessel to be making 10.419 knots, whilst the "simple" only made 10.14 knots. The greater speed of the former may probably be due in part to a slight excess of engine power; but I am inclined to think that more is due to the more uniform distribution of the power round the path of the crank, and that that machine which gave the more steady and uniform motion to the propeller, pushed the ship the fastest through the water.

The compound engines of the "Briton" I found to be even more uniform than those of the "Goshawk"; the pressures in that case varied from 7.91 tons to 17.16 tons, or the highest was only 2.1 times that of the lowest.

I believe the question of a uniform tangential force is of more importance than is often considered, both for propeling the ship, as well as for the less liability to rupture of the different working parts which rupture is more often due to suddenness and change of strain than to a constant steady pressure.

Taking the above named pressures in each class of engines, I found by keeping the shafts and other working parts of equivalent strength, which would probably give a total weight of somewhat under five per cent. for the pressures they had to sustain, that the simple engine was about one-tenth heavier than the compound engine, of course, irrespective of boilers, which would be common to both.

To show how important it is to take into consideration the tangential forces in the crank-path, I found, in making different calculations for finding the best position to place the cranks of the compound three cylinder engines of the "Boadicea" and "Bacchante," of 5,250 horse-power each, that if the cranks were placed at equal angles between them, the shaft should be 18 inches diameter, but if placed with the two low-pressure cranks opposite to each other, and the high-pressure crank at right angles to them, that the shaft need not be more than 16 inches to be of equal strength to transmit the same total power.

The *simple engine*, or engine with two cylinders of the same size, working with a pressure of from 60 to 70 lbs. direct on the pistons, has been tried in more than one Transatlantic Company. One of them had, I believe, four vessels with such engines, but it was eventually found necessary to reduce the pressures some 20 lbs. per square inch in consequence of the crank-shafts continually breaking, but, according to the usual mode of calculating the strain on the shafts, they ought to have been amply strong enough

case (which is not uncommon) I think it highly probable that with the simple engine, with 60 or 70 lbs. on one side of the piston and a vacuum on the other, a much larger consumption of steam and coal will take place than with the compound cylinders, where the pressure is at the boiler pressure on one side of the piston, and some 5 or 10 lbs. above atmospheric pressure on the other; moreover, should any leakage of steam take place by the high-pressure piston, it will have a chance of being used in the low-pressure cylinder before being discharged into the condenser.

for the intended pressures, and I can only account for it by the sudden and irregular strains on the shafts due to the high initial pressure and early "cut off."

It has been supposed by some that the weight of the screw propeller is sufficient to act as a fly-wheel to give an equitable rotative motion in propelling the ship; but I think that any one who has observed the working of a powerful engine on board ship must have seen that such is not the case: there is usually one part of the revolution of the shaft that appears to have greater power exerted through it, and it is felt in the motion of the ship. It has always appeared to me that I have felt less motion with the compound engine than with the old type.

One objection that has been used with reference to the compound engine is, that the low pressure cylinders in engines of great power become of so large a size as to render the castings excessively heavy, and that many of them have cracked after being in use. This difficulty is in a great measure obviated by making an inside liner of a separate piece from the body of the casting, and forming a space between them for a steam jacket, instead of casting the whole in one. The system of having two low-pressure cylinders to one high-pressure cylinder, as in the "Boadicea," or by having two low-pressure cylinders and two high-pressure cylinders, as in the "Minia" type, also prevents any objection on that score.

It has been sometimes asserted that the increased surface subject to radiation in the compound cylinders has tended to a loss of heat; but on the other hand it must be remembered that the increased size also gives an increased surface of steam jacketing to warm up the steam inside the cylinder.

Some interesting particulars have lately been published with reference to the trials made with the engines of the United States' Coast Survey steamer "Bache." These seem to have been made with and without a steam jacket on the compound cylinders compared with the same pressure of steam (80 lbs. per square inch), used in a single cylinder alone, also with and without the steam jacket. The high-pressure cylinder was about 16 inches diameter, and the low-pressure 25 inches, stroke in both being 2 feet. The results, *without steam* in the jackets when working as a compound engine, appear to indicate that there is not any material difference in the consumption of steam and coal per indicated horse-power by using the different grades of expansion, which varied from 5.6 to 9.14 times total expansion, with a consumption of coal only varying from 2.54 lbs. to 2.6 lbs. per indicated horse-power per hour. Whereas when the single large cylinder alone was used without the steam jacket admitting the steam pressure of the boiler, viz., 80 lbs. per square inch, direct on to the piston and "cutting off" by means of an independent valve, the consumption per indicated horse-power appears to increase when the expansion of the steam is greater, that is, with a ratio of expansion varying from 5.3 to 11.8 times. The coal per indicated horse-power varies from 2.874 lbs. to 3.84 lbs.; but when steam was admitted into the jackets (and selecting two trials from each series of experiments which more favorably compare), the compound cylinders had a ratio of expansion of steam of 5.7 and 9.19, with a corresponding consumption of coal of 2.23 and 2.26 lbs. respectively, and with the single with steam in the jacket with an expansion of 5.1 and 8.57 times and a consumption of 2.53 and 2.638 respectively, that is, the result is rather in favor of the compound engine in point of consumption of steam and coal. That this is due to any advantage of expanding the steam in two cylinders instead of in one I am not inclined to think, but probably to some difference in the vacuum, coal, or stoking, besides the slight difference in the expansion, or to leakage of steam by the piston.

The initial pressure on the large piston, after the steam has done its duty in the small one, is given as 18.99 lbs. (say 20 lbs.), but when the steam is acting direct on the large piston for working on the simple plan, then the initial pressure is as high as 90.14 lbs. (say 90 lbs.), the average revolutions in the first case being 48 and the second 46½, the horse-power being 77.45 and 74.6 respectively.

It may therefore be said with the same horse-power and same number of revolutions that the total pressure on the compound cylinder would be 1 and on

the simple cylinder $4\frac{1}{2}$; but supposing—to fairly represent the difference—there were two cylinders at half the size to compare with the two cylinders of the compound engine, the proportion of the pressures would be as $2\frac{1}{4}$ to one, and the working parts would have to be increased at least in corresponding proportion to be of equal strength to the parts of the compound engine.

In actual practice in marine engines, it may happen that the smaller diameter of the "simple engine" may be still further reduced, in consequence of the form of the ship admitting of the cylinders being placed more in the wing, which may still further enable the diameters to be reduced and the stroke increased in proportion.

It seems to me that the compound engine must be looked on in the light of a most convenient mechanical arrangement for working with a high pressure of steam and great expansion; and should very much higher pressures than 60 or 70 lbs. per square inch come into use—and I believe it has been proposed to make some engines for the navy for working with from 250 lbs. to 300 lbs. pressures—it seems to me that some system of compound must of necessity be adopted, and that with three or more cylinders in lieu of two, as is now usual.

The following, I therefore think, may be the summary of the comparative merit of the simple and compound engine:

1st. With equal amount of pressures, expansion, dryness of steam, the coal consumed will be practically identical in both systems, supposing the pistons tight.

2nd. When equal power is obtained, the working parts of the simple engine will have to be heavier than the compound.

3rd. The strains on the compound engine being more uniform, there will be less liability to fracture in the working parts.

4th. The simple engine with two cylinders of the same size will have the advantage of having fewer pieces of spare gear to stow away.

5th. The simple engine having each cylinder independent of the other can be more readily worked with one engine than with the compound engine, should one engine be disabled.

6th. For the same power of engine, it is probable that a greater speed of ship may be obtained with the compound engine than with the simple engine.

7th. If much higher boiler-pressures come into use than are now usually worked, the compound engine will have to be exclusively adopted, on account of the better mechanical arrangements which can be made for working with a high degree of expansion.

Iron Ore in the South of Russia.—These new fields (recently discovered) of beautiful iron ore are situated partly in the Verchni-Dnieprovsky district of the Ekaterinoslaw Government, partly in the Elizavetgradsky district of the Cherson Government; iron ore is found here on the rivers Saksagane and Ingouletz, near the village Krivoy-Rog. About twelves miles from this place on the river Saksagane, near the village Tchervonnaia-Balka, large quantities of red hæmatite are found. Immense layers of hæmatite, 100 feet thick, are situated near the river Ingouletz and the village Doubovaia-Balka. The best layers of iron ore are the following:

(1) On the left side of Ingouletz and on the right of Saksagane, between the village of Kirvoy-Rog and Doubovaia-Balka, is a layer of ironstone 120 feet thick; the results of the analyses are: Oxyde of iron, 68.40 per cent.; manganese, 0.50; silica, 22.10; alumina, 3.00; lost from ignition, 6.00 per cent.; total, 100.00.

(2) On the left side of the river Saksagane a layer of red hæmatite 42 feet thick; gives 62.5 per cent. of oxyde of iron.

(3) On the same river Saksagane exist layers of magnetic iron ore and of brown hæmatite; a sample of the latter analyzed gave the following average composition: Oxyde of iron, 73.40 per cent.; manganese, 1.30; silica, 18.03; alumina, 2.25; lost from ignition, 5.02; total, 100.00 per cent.

It is estimated that the new fields of iron ores contain altogether 90,000,000 tons of ore. There is a railway going to be constructed to these mines, and some blast-furnaces are to be erected.

THE BEHAVIOR OF METALS UNDER REPEATED STRAINS.

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I.

IN vols. X., XIII., XVI. and XX. of the *Zeitschrift f. Bauwesen* are published the experiments of A. Wöhler upon the strength of iron and steel, with a description of the apparatus used, a statement of his views of the laws, and a mathematical comparison of the different kinds of resistance. Afterwards Wöhler, induced by the novelty of the results obtained, requested the Industrial Bureau to authorize the repetition of his experiments. At the suggestion of Prof. Reuleaux, the writer was intrusted with the investigation.

We quote the laws deduced by Wöhler, and give a brief account of his processes. He says:

"Rupture of material may be caused by repeated vibrations, none of which attain the absolute breaking limit."

Assuming the lower limit of tension at zero, it follows from this law that the number of repeated strains necessary for rupture is inversely proportional to the greatest tension borne by the fibres which are subject to greatest strain.

Wöhler's apparatus was of four kinds:

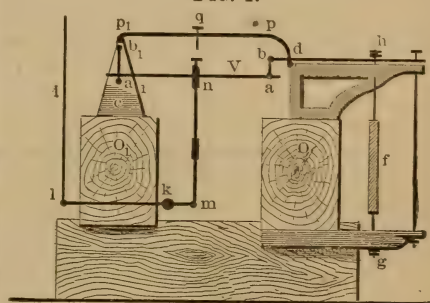
(1) For rupture by repeated load.
(2) For repeated bending in one direction of prismatic rods.
(3) For experiments on loaded rods under constant bending strain.
(4) For torsion by repeated load (strain).

The power was transmitted by a shaft to (1), (2) and (4) by means of an eccentric; to (3) by a drum on a steel shaft having ends with conical bores, into which the piece subjected to torsion was fastened with an apparatus of screws.

Apparatus (2) is shown in the diagram (Fig. 1).

The rod to be tested rests upon the supports a and a, which are connected with the link pieces $a\,b$ and $a_1\,b_1$; the latter turning at b_1 in the cast iron block c; the first being attached to the short arm of the lever $b\,e$. The spring dynanometer f, which can be stretched within certain limits by screws at g and h, prevents the long arm from rising when the short is loaded. The strain is applied by means of the eccentric-rod i. This is connected with the lever $l\,m$, whose fulcrum is at k; so

FIG. 1.



$^1/_{36}$ n. s.

that when the rod rises the end m descends, and transmits a bending strain through $m\,n$ to the rod V, then to b and b_1. Six of these machines are set upon the beds O and O; so as to be operated by the same rod i. If each of the six test rods is to be subjected to maximum strain, the dynanometer f operates as follows:

Let S'=the required maximum tension per square unit.
b=the width of the test-rod.
h=the depth of the test-rod.
$a\,a_1=l$.
P=the required strain at the middle; then we have

$$P=\frac{4}{b}S\frac{b\,h^2}{l}$$

This force is borne equally at a and a_1, so that $\frac{P}{2}$ at b acts downward, and is balanced by the tension S of the dynanometer and the excess of weight of the rod $d\,e$. If H is the weight of the lever reduced to the point h, then $\frac{b\,d}{d\,h}=\frac{1}{n}$

$$\text{And } S=\frac{P}{2\,n}-H.$$

As long as the *f* strain *k* on *m n* is less than P, the point *a* must be regarded as fixed, and the rod V bends; but when *k* is greater than P, the point *b* yields, and while the rod is under bending strain there is a rotation of V about a_1, which is shown at the end of the lever *e*.

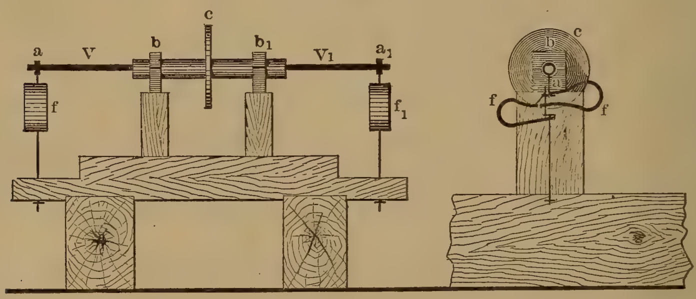
The rod *m n* has at the top a stirrup through which passes the rod to be tested; and at the lower end is a slot in which is fixed a pin attached to the lever *l m*, so that when the rod *i* rises a downward pull is caused; but when it descends the rod is set free and is restored by its own elasticity to its first position. In the middle of the rod *m n* is a screw with a nut to adjust the length, so that only for a moment before the point *n* reaches its lowest position, does the point *a* descend. The tension is therefore maintained for a very short time.

If the tension is to be restored, not to zero, but to some minimum value, the screw *q* is set down so as to keep the rod bent the required amount.

In a similar way the limiting strains in apparatus (1) and (4) are determined, while in (3) the constant deflection of the rod is produced by a spring dynanometer *f* (Fig. 2).

Each fibre, except those lying in the neutral plane, was subjected first to compression, then to tension.

FIG. 2.



$^1/_{36}$ n. s.

Wöhler, after testing a metal to the limits of elasticity and rupture in the ordinary way, had rods made of the same metal, and subjected the first test-rod of each set to a tension nearly equal to the absolute rupturing strain. Each successive rod of the same set of experiments was subjected to a diminished strain. It appeared that the number of strains required for rupture increased much more rapidly than the strains diminished.

Diminish the intensity of the strains until the number is reached which a member of any structure, subjected to repeated stresses, may bear before becoming crippled, and introduce a safety factor $\frac{1}{n}$ (which Wöhler makes $\frac{1}{2}$) and we have the value of the permissible strain. The *practical* proof strain is thus directly determined.

Wöhler found that a rod of Krupp's cast steel, under a maximum tension of 300 Ctr. per square inch (German), was broken in apparatus (3) after 4,500,000 revolutions. If this metal were used in an axle which had to make 30,000 rotations per day, or 9,000,000 per year; then for five years' duration (with coefficient $\frac{1}{2}$), the working strain would be 150 Ctr. per square inch. Another experiment showed that a rod of Phœnix iron after a maximum strain of 160 Ctr. per square inch after 132,250,000 revolutions was still in working condition. Wohler concludes that the working strength of iron suffering alternate compression and tension is 80 Ctr. per square inch, for a structure intended to be permanent.

Numerous experiments establish Wohler's second deduction that:

Differences of strains at the extremes of vibration are a sufficient cause of rupture of continuity; and the absolute magnitude of extreme strain is effective only in this respect; that as the strain increases the differences which are sufficient to cause rupture become less.

The experiments show that vibrations may take place between the following

limits of strength with equal security against rupture by tearing or crushing.

Iron	bet. + 160 Ctr. and — 160 Ctr.
	bet. + 300 Ctr. and — 0 Ctr.
	bet. + 440 Ctr. and + 246 Ctr.

Strain per square inch.

Axle Steel Cast.	bet. + 280 Ctr. and — 280 Ctr.
	bet. + 480 Ctr. and 0 Ctr.
	bet. + 800 Ctr. and + 350 Ctr.

Strain per square inch.

Spring Steel not hardened.	bet. + 500 Ctr. & 0 Ctr.
	bet. + 700 Ctr. & + 250 Ctr.
	bet. + 800 Ctr. & + 400 Ctr.
	bet. + 900 Ctr. & + 600 Ctr.

Strain per square inch.

And for shearing resistance:

Axle Steel Cast.	bet. + 220 Ctr. & – 220 Ctr.
	bet. + 380 Ctr. & 0 Ctr.

Shearing stress per square inch.

Pieces which are subjected to alternate pull and thrust, as piston rods, &c., must be about 9.5 stronger than those bearing but one kind of stress.

In the *Zeitchr. f. Bauw.* for 1870, p. 87, Wohler says:

"The results of the experiments give the following working strains for permanent structures:—(*a*) For forge iron strained in both directions 80 Ctr. per square inch; in one direction, 180 Ctr. per square inch, of which 150 Ctr. at the most may be due to the variable load.

"If the constant strain is less than 30 Ctr., the permissible working strain is diminished.

"(*b*) For cast steel not hardened, strained in both directions, 120 Ctr. per square inch; strained in one direction, greatest total strain 330 Ctr. per square inch, of which 220 Ctr. at most may be due to the variable stress. (The figures apply only to dressed rods.")

Having given an account of the nature and results of Wohler's experiments and of his conclusions, we now pass to our own experiments.

In November, 1872, we tested the Phosphorbronze of Künzel from Hoper's Works at Iserlohn. At the same time tests were made of common bronze from the Neptune Continental Works. The results are given in Tables III., VI. and IX.

In 1873, we received 52 cast steel bars from Krupp, cut by him from a locomotive axle; the results of experiments on these are given in Tables II. and VIII.

Few experiments could be made with Machine IV., because but one bar could be tested at one time. But the results are worth recording (Table IX.), because they indicate a valuable property of phosphorbronze.

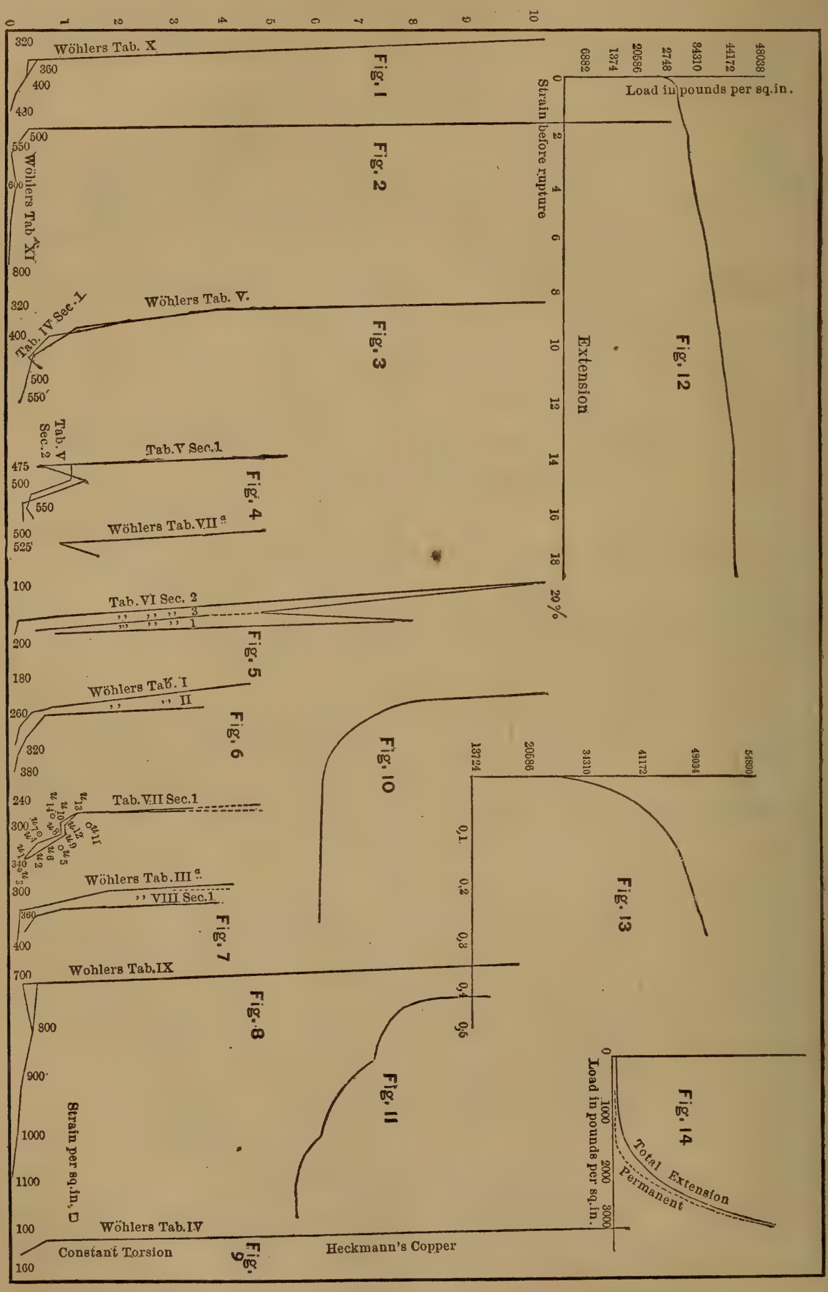
The diagrams annexed correspond to the tables. With regard to his Table I., Wohler says:—"The number of rotations before rupture increases inversely as the strain. The irregularities, which must be attributed to the want of homogeneity of material, are so great that no certain law can be derived from this set. The deviation is greatest at 220 Ctr. Ignoring this case, it appears that the number of rotations increase more rapidly in geometric progression than do the loads in arithmetical. With the greatest strain the number of rotations doubled for a difference in load of 24 Ctr.; and it doubled with the lowest strain for a difference of 10 Ctr."

To make this clear, Fig. 6 is drawn, in which the strains are laid off as abscissae, and the number of rotations before rupture as ordinates. This may be easily represented as a curve by leaving out the uncertain point u (220), and connecting the extremity of the ordinate of 240 with that of 200. It is not necessary to regard the point u as taken too high; for although u_1 would be too low, still we should have a curve agreeing with Fig. 10. Finally, u may be regarded as a reversion-point, the curve having a form agreeing with that shown in Fig. 11. Which of these three hypotheses is most probable can be only determined by at least three complete sets of experiments with the same material; Wohler having made but one set, except in particular cases of great doubt. As we shall often refer to these curves, we only remark here that the most interesting of the tables are illustrated in Figs. 1 to 9 on the diagram sheet.

Table II. contains Wohler's results showing the inequalities of Firth & Sons' tool steel; which is a matter of surprise when it is known that the sections of rupture were homogeneous in appearance. We attribute the fact to the presence of a large percentage of carbon; the steel being intended for tools, not

for axles. For this reason we have not subjected it to continued torsion.

A decided difference in hardness appeared in rods 3 and 4; so that the remainder were heated dull-red, and were cooled slowly under warm ashes, so that the hardness was made more uniform without affecting the strength.



Tables III. and IV. show that Kunzel's phosphorbronze has much more strength than common bronze and brass. Wrought, *i. e.* cold-beaten phosphorbronze does not seem to have as much strength as that which is cast. Wrought phosphorbronze

shows a very rough, irregular fracture, while the cast breaks with a surface like that of cast-steel, indicating homogeneity of material. In this respect, common bronze and brass more resemble iron. Brass is hardly on equal terms with phosphorbronze in respect to absolute strength ; there is a closer equality in

A. Repeated Stretching. I. to III.

Table I.

1872–4. Westphalia Iron.			Wohler's Tab. X. Phœnix Iron.	
No.	Maximum Strain per square inch Ctr.*	No. of rotations before rupture.	Maximum Strain per square inch Ctr.	No. of rotations before rupture.
1	480	4700	480	800
2	440	83199	440	106910
3	440	33230	—	—
4	400	136700	400	340853
5	400	159639	—	—
6	360	180800	360	409481
7	360	596089	360	480852
8	360	433572	—	—
9	320	280121	320	10141645
10	320	566344	—	—

* The Centner (Ctr.) = 110 lbs. English. | 9 and 10 showed welding joints.

Table II. Steel.

1872–4. Firth & Sons' Steel.			Krupp's Axle Steel.		Wohler's Tab. XI. Krupp's Axle Steel.	
No.	Max. Str. per sq. in. Ctr.	No. of tensions before rupture.	Max. tens. per sq. in. Ctr.	No. of tensions before rupture.	Max. Str. per sq. in. Ctr.	No. of tensions before rupture.
					800	18741
			640	81400	700	46286
1	600	83319	—	—	600	170000
2	550	168396	—	—	550	123770
3	500	133910	500	429000	500	473766
4	500	185680	—	—	—	—
5	500	360235	—	—	—	—
6	500	186005	—	—	—	—
7	490	103540	—	—	—	—
8	490	Sound after 12,₂ Mil.	—	—	—	—
9	480	229230	—	—	480	Sound after 13,₆ Mil.
10	480	692543	—	—	460	Sound after 12,₂ Mil.
11	460	Sound after 12,₂ Mil.	—	—	—	—

1 and 2 and 5–11 were heated a little and cooled very slowly ; 3 and 4 were as they came from the rolling mill.

respect to bending. With axial strain, common bronze and brass broke at 200 resp. 150 Ctr. maximum fibre tension when the tension rod was shortened ; but under transverse load with equal maximum tension, they bore millions of

stresses. It is obvious that it is not safe to infer that the behavior of a metal will be the same under different kinds of strain. Hence, we cannot agree with Wohler that it is sufficient to make experiments in one kind and deduce results for others.

TABLE III. BRONZE AND BRASS.

a. Phosphorbronze (unworked).			*b.* Phosphorbronze (wrought).		
No.	Maxi. Strain per square in. Ctr.	No. of rotations before rupture.	No.	Max. Strain per square in. Ctr.	No. of rotations before rupture.
1	250	147850	—	—	—
2	200	408350	1	200	53900
	—	—	—	—	—
3	150	2731161	2	150	Sound after $2,_6$ Mil.
4	125	1548920	3	125	1621300
5	125	2340000			
No. 3 was very hard.					
c. Common Bronze.			*d.* Brass.		
	—	—	—	—	—
1	200	0	—	—	—
2	200	4200	1	200	0
3	150	6300	2	150	0
4	100	5447600		100	53000
No. 1 broke by shortening of tension rod before 200 Ctr.			1 and 2 broke before 200 and 150 Ctr.		

B. REPEATED BENDING IN ONE DIRECTION. TABLE IV. TO VI.

TABLE IV.

Westphalia Iron.			Wohler's Tab. V. Phœnix Iron.		Wohler's Table VI. Homogen. Iron.	
No.	Max. Str. per sq. in. Ctr.	No. of bendings before rupture.	Max. Str. per sq. in. Ctr.	No. of bendings before rupture.	Max. Str. per sq. in. Ctr.	No of bendings before rupture.
	—	—	550	169750	—	—
	—	—	500	420000	—	—
1	475	612065	—	—	$^{800}/_{400}$	475500
2	450	457229	450	481975	$^{700}/_{300}$	1234600
3	425	799543				
4	400	1493511	400	1320000	400	Sound after 34500000
5	360	3587509	360	4035400		
			320	Sound after 3420000		
			300	Sound after 48200000		

Table IX. confirms our opinion Comparison of Tables III. with I. and II. shows that phosphorbronze under 250

Ctr. does not stand as many extensions as Phœnix or Westphalia iron under 400 Ctr. and steel under 600 Ctr. Comparing Table VI. with Tables IV. and V., we observe that phosphorbronze at 200 Ctr. tension does not bear as many bending strains as Westphalia, Phœnix or Homog. Iron at 400 and steel at 500 Ctr. The torsion tables show that phosphorbronze has a greater resistance to torsion than Krupp's cast-steel and Westphalia iron. This result was so surprising that we interrupted Test 3 in order to substitute the new rod of Test 4. Still we were in doubt, and therefore substituted experiment 5, which confirmed the previous results. Should further experiments give like results, then phosphorbronze, which is little affected by the action of sea water, must be employed in the axles of propeller screws.

The profiles of Fig. 5, correspond to

TABLE V. STEEL.

1872–4. Firth & Sons' Steel.			1873–4. Krupp's Axle Steel.			Wohler's Table VII. *a.* Krupp's Axle Steel.		Wohler's Table VII. *b.* Bochumer Verein Axle Steel	
No.	Max. Strain per square in. Ctr.	No. of bendings before rupture.	No.	Max. Strain per square in. Ctr.	No. of bendings before rupture.	Max. Strain per square in. Ctr.	No. of bendings before rupture.	Max. Strain per square in. Ctr.	No. of bendings before rupture.
								700	104300
						—	—	600	317275
1	575	281856	1	575	443800	—	—	—	—
2	550	2665[illegible]6	2	550	423400	550	1762300	550	612500
	—	—	3	525	513000	525	1031200	—	—
	—	—	—	—		520	1477400	—	—
3	500	1479908	4	500	1177400	500	5234200	500	729400
	—	—	—	—		500	Sou'd after $40,_6$ Mil.	500	1499600
4	475	578323	5	475	1185100	—	—	—	—
5	450	5640596	6	450	Sou'd after $1,_7$ Mil.	—	—	450	Sou'd after 43 Mil.
6	450	Sou'd after $13,_7$ Mil.		—		—	—	—	—
			7	425	Sou'd after $1,_7$ Mil.	—	—	—	—

1–5 incl. were heated a little, and cooled very slowly.

5 broke accidentally.

TABLE VI. BRONZE AND BRASS.

Phosphorbronze.			Common Bronze.			Brass.		
No.	Max. St. per sq. inch. Ctr.	No. of bendings before rupture.	No.	Max. St. per sq. inch. Ctr.	No. of bendings before rupture.	No.	Max. St. per sq. inch. Ctr.	No. of bendings before rupture.
1	200	862980	1	200	102650	1	200	253100
2	180	8151811	2	180	151310	2	180	1934400
								Sound after $5,_6$ Mil.
3	150	5075160	3	150	837760	3	150	
		Sound after 10 Mil.			Sound after $10,_4$ Mil.			
4	120		4	120		—	—	—

Table VI. That of common bronze appears most regular, showing the material to be of good quality. According to Dr. Künzel (Polyt. Centralblatt, Jan.

1874,) when a phosphorbronze axle is heated to a low red heat a very soft alloy of tin and lead is melted out, leaving the axle hard and spongy. Perhaps in this phenomenon is to be found an explanation of the peculiar behavior of the metal in respect to torsion.

Table IV. (divisions 1 and 2) is represented in Fig. 3. Both polygons agree fairly, leaving out of notice rod 1, whose deflection number is obviously too large.

Fig. 4 corresponds to the first three divisions of Table V. The profile of division 1, is very similar to Wohlers Table VII., to which we shall recur. Frith's steel seems to have a resistance of about 20 Ctr. less per square inch than the older cast steel of Krupp.

Table VII. is represented in Fig. 6 While the first two profiles indicate greater uniformity and strength of homogeneous iron than of Phœnix iron, we found that for spindle iron it was hardly possible to work out a profile including the points from u_2 to u_{16}. We went through with 3 sets of tests between 280 and 340 Ctr., and through 2 sets with strains less than 280, taking differences of 20 Ctr. We hoped to obtain a polygon agreeing with Fig. 10, by taking the arithmetical mean of 3 corresponding rotation numbers; but were disappointed. The great difference in the positions of the points corresponding to the same strain, is due not only to the want of homogeneity in the iron but also to errors in determining the number of

C. Continued Loads. Tab. VII. and VIII.

Table VII. Iron.

	1872–3. English Spindle Iron.		Wohler's Table I. Phœnix Iron.		Wohler's Table II. Homogen. Iron.	
No.	Max. Str. per sq. in. Ctr.	No. of rotations before rupture.	Max. Str. per sq. in. Ctr.	No. of rotations before rupture.	Max. Str. per sq. in. Ctr.	No. of rotations before rupture.
	—	—	—	—	380	31586
1	340	r_1 204200	—	—	340	94311
2	340	r_2 204400	—	—	—	—
3	340	r_3 147800	—	—	—	—
	348)		—			
4	320	402900	320	56430	—	—
5	320	911100	—	—	—	—
6	320	503500	—	—	—	—
7	300	384800	300	99000	300	161262
8	300	1035300	—	—	—	—
9	300	1064700	—	—	—	—
10	280	979100	280	183145	280	464786
11	280	1337700	—	—	—	—
12	280	1066000	—	—	—	—
13	260	1142600	260	479490	260	636500
14	260	595910	—	—	—	—
		Sound after				
15	240	6,1 Mil.	—	—	—	—
16	240	3823200	240	909810	240	3930150
		Sound after	220	3632588		
17	200	8,8 Mil.	200	4917992	—	—
		Sound after				
18	200	4 Mil.	—	—	—	—
			180	19186791		
				Sound after		
			160	132 Mil.		

rotations, caused by defects in machinery. After these were cured the following tests were made and accurately registered : viz. the last 2.7 millions of 16, 17, 18 and the last 2.3 millions of No. 16.

We now give attention to the several points u which give a profile probably correct.

The points u and u_2 fairly agree ; but rod No. 3, under 340 Ctr. strain could

not be counted, because of an accident that increased the strain by 8 Ctr. In Wohler's Table I. u_5 and u_7 may be rejected, the first as too high, the second, as too low. Whether u_{13} or u_{14} is the more correct could not be determined by two experiments, but we have set u_{13} nearer u_{10} and u_{12}. Hence the profile in Fig 6.

In considering the possible errors, if the lowest points only are regarded the profile u_3, u_7, u_{14}, u_{16} results which seems probably correct. But the question must be settled by experiment.

Only the first two divisions of Table VIII. are represented in Fig. 7; the third showing too great differences, and the fourth not agreeing with the foregoing.

Both profiles are similar, except that

TABLE VIII. STEEL.

	1873–4. Krupp's Axle Steel.		Wohler's Table III. Krupp's Axle Steel.		Wohler's Tab. III. Bochumer Verein Axle Steel. 1863.		Wohler's Tab. III. Borsig Axle Steel. 1863.	
No.	Max. Strain per square in. Ctr.	No. of rotations before rupture.	Max. Strain per square in. Ctr.	No. of rotations before rupture.	Max. Strain per square in. Ctr.	No. of rotations before rupture.	Max. Strain per square in. Ctr.	No. of rotations before rupture.
	—	—	420	55100	—	—	—	—
1	400	367400	—	—	—	—	—	—
2	380	428250	—	—	—	—	380	157700
3	360	925800	360	127775	360	127775	360	239875
4	340	Sou'd after 4,9 Mil.	340	797525	340	342850	340	553850
5	320	Sou'd after 4,8 Mil.	320	642675	320	627000	320	1373225
—	—	—	320	1665580	320	20467780		
—	—	—	320	3114160	—	—		
6	300	Sou'd after 5 Mil.	300	4163375	300	2845250 Sou'd after 57 Mil.	300	1025625
			300	45050640				
					280	3558700		

the one corresponding to Krupp's new steel is much higher than that of the old, showing an improvement in the manufacture.

In No. 6 appears a more careful diagram of the experiments of Table VII., made with the hope of being able to deduce the equations of the curves. This has not yet been accomplished. The experiments of Wohler were for the most part with the Phœnix axle iron and with tool steel and cast-spring steel. His tests of rails by torsion (having a special object in view) are not important because they are not subjected to that kind of strain.

In our attempt to collect the results of experiments, we received valuable information from a paper by Launhardt (Zeits, des Arch.-und Ing.-Ver. Zu Hannover 1873, Heft. II.). He gives the name of working resistance to that (greatest) amount of strain which is not sufficient to break the material after an indefinite number of applications; and of original resistance (ursprungsfestigkeit) to the amount when the material is allowed to a strainless condition, instead of to some minimum strain. He regards the working resistance (a) as a function of the breaking resistance (b), the original resistance (u), or of the ratio

$$\frac{\text{S min.}}{\text{S max.}}=\frac{\text{Its own weight}}{\text{total load}}$$

and employs the formula

$$a=u\left(1+\frac{b-u}{u}\cdot\frac{\text{S min.}}{\text{S max.}}\right)$$

With reference to Wohler's results for cast steel

$$a=500\left(1+\frac{6}{5}\frac{\text{S min.}}{\text{S max.}}\right)\text{ Ctr. per sq. in}$$

And for wrought iron

$$a=300\left(1+\frac{5}{6}\cdot\frac{\text{S min.}}{\text{S max.}}\right)$$

These formulas are of some practical value; but they would be more trustworthy if they had been derived by direct experiments on material for bridges.

Wohler's experiments have required a period of 12 years; and a time equally long would be necessary to obtain a complete set of parallel tests for bridge material, unless the curve equation for some material recognized as good could be obtained. It would then be necessary to try a few tests only of high strains upon any other metal in order to determine with respect to quality, homogeneity and resistance. For example; assuming Fig 6 as such a "normal curve" the figure shows that the second polygon (Hom. iron) corresponds to a stronger material than does the first, since the latter at 240 Ctr. strain shows just as many rotations as the former at 210 Ctr. And it may be conjectured that the working resistance of homogeneous iron is at least 190 Ctr., while that of Phœnix iron is 160 Ctr. If this is clear on a diagram to a very small scale, it would be more certain if the normal curve were known.

Of course the number of rotations u, of a material diminish when the strains increase and conversely. Hence we may assume $u=f\left(\frac{1}{S}\right)$. Substituting in the formula

$$y=A+Bx+Cx^2+Dx^3+\&c.$$

u for y and $\frac{1}{S}$ for x.

we have

D. Experiments with Rods bent in Two Directions.

Table IX.

Material.	No.	Maximum Strain per square inch. Ctr.	No. of rotations before rupture.
Westphalia Iron of 1872–4.......	1	240	431306
Firth & Sons' Cast Steel.........	2	240	Crippled after 6497800
Hammered Phosphorbronze......	3	240—320	Crippled after 14916800
" "	4	300—360	4032680
" "	5	360	Sound after 1301600
Wohler's Table XIII.			
Krupp's 1862 Cast Steel		260	1007550
....		240	859700

Remarks.—No. 3 had borne under a strain of 240 Ctr............7743000
Again under a strain of 300 Ctr............3993800
Again under a strain of 320 Ctr............3180000

14916800

And dynanometer allowed no higher strain.

No. 4 had a smaller diameter than No. 3, and had borne
Under 300 Ctr. strain............1000000
Under 320 Ctr. strain............1200000
Under 340 Ctr. strain............8000000
Under 360 Ctr. strain............1032680

4032680
Before rupture.

$$u = A + \frac{B}{S} + \frac{C}{S^2} + \frac{D}{S^3} + \&c.$$

If we close this series say at the 4th term, the co-efficients A, B, C, D can be determined by 4 experiments. If more experiments, say 8, 12 or 16, were made, then they would be determined with greater accuracy by the method of Least Squares; remembering that if S is infinite $u = 0$ and, therefore, $A = 0$. As the experiments show that u increases either in simple or quadratic ratio if S diminishes arithmetically, at least 3 terms must be taken, so that we have

$$u = \frac{B}{S} + \frac{C}{S^2} + \frac{D}{S^3}$$

If Newton's or Lagrange's formula of interpolation is used, it is better to make $y = \frac{1}{u}$ and $x = S$, giving the equation $A S^3 + b S^2 + C S = \frac{1}{u}$; because the successive values of S can be taken with equal difference, so as to simplify the calculation. Whether the series so found is sufficiently convergent to determine the coefficients B, C, D from a few experiments so as to give trustworthy values for u, cannot be determined *a priori*; for the coefficients of safety must be first fixed by a great number of experiments.

Wohler's tables require a careful revision. First with regard to division No. 1, viz.:

$$\text{For iron} \left\{ \begin{array}{lll} \text{bet. } + 160 & \text{and} & -160 \text{ Ctr.} \\ \text{bet. } + 300 & \text{and} & 0 \text{ Ctr.} \\ \text{bet. } + 400 & \text{and} & +240 \text{ Ctr.} \end{array} \right\}$$

Tension per square inch.

Both limits, + 160 and — 160, agree with Wohler's Table I. for continuous torsion and Phœnix iron; the corresponding rotation-number 132¼ million is regarded as "unlimited duration." If, according to Wohler (Zeits. f. Bauw., 1858, p. 446), the maximum duration of an axle corresponds to a run of 200,000 miles, and the circumference of the wheel makes 2,400 revolutions per mile, then 480 million revolutions are sufficient to wear out the axle. Now, it is not certain that rod No. 9 of Wohler's Table I., after 132 millions, would stand 348 million more; but it is probable; because for equi-different strains the number of rotations increases in a ratio higher than the duplicate, and the number of rod No. 8 is 19 millions. For axle torsion, these limits hold; but not for axle compression and tension, as in the case of piston-rods; for according to Wohler's Table X. a rod of Phœnix iron was torn apart under a strain of 320 Ctr. after 10,100,000 tensions, and therefore would not have borne alternate strains of tension and compression to the number of 10 millions. Hence, although in the tables, to ensure two-fold security for wrought iron strained permanently in both directions, the strain 80 Ctr. per square inch is assigned as permissible; still this can be accepted only for the coefficient 2, which must therefore have another office besides that of compensating for the non-homogeneity of the material. In this regard Launhardt's coefficient ⅓ seems to be worth testing by further experiments; especially for iron when greater resistance is called for in one direction than in the other.

The limits 300 and 0 are derived from Wohler's Table V., rod 7, which was sound after 48 million bendings. The jump from 360 with 4 million to 300 with unlimited number, is somewhat conjectural; and the assumption is made probable only by Fig. 3. The assumption derived from Table X. that for 300 Ctr. strain the duration is "unlimited," because for 320 Ctr. strain rupture was sound after 100 million extensions, is not justified either by the table or Fig. 1; so that Wohler's assumption that the "original resistance," shown in bending, agrees with that shown in extension, requires the confirmation of experiment.

The third pair, +440 and +240, agree with Wohler's Table X. Rod 8 was in working order after 4 million extensions, while rod 7 under $\frac{400}{200}$ strains bore only 2,400,000 extensions. It seems unsafe to draw conclusions from these results without further tests.

The 2d division gives results which are more certain, viz.:

$$\text{Axle steel} \left\{ \begin{array}{lll} \text{bet. } + 280 & \text{and} & -280 \text{ Ctr.} \\ \text{bet. } + 480 & \text{and} & 0 \text{ Ctr.} \\ \text{bet. } + 500 & \text{and} & +350 \text{ Ctr.} \end{array} \right\}$$

Strain per square inch.

The limits $\frac{+280}{-280}$ are more exact, because for $\frac{+300}{-300}$ the numbers of rotations

rose to 45 millions. Less reliable is $\frac{450}{0}$ and $\frac{800}{300}$ from Wohler's Table XII., since from $13,_6$ millions, with respect to 12 millions, an "indefinite duration" was indicated.

The 2d division is:

For unhardened spring cast steel.	between 500 and 0 Ctr. between 700 and 250 Ctr. between 800 and 900 Ctr. between 900 and 600 Ctr.

Strain per square inch.

Here there is no doubt, since the 4 experiments were made with the same metal, and the bending numbers varied between $44,_6$ and $33,_6$ millions, which may be regarded as "unlimited duration," in view of the uniformity of the metal and the number of tests. The same may be said of the part respecting torsion.

The experiments with spring steel may be regarded as conclusive; and there remained for us only to repeat the tests on axle steel, and on metals for railway bridges and permanent way.

[The writer here regrets that his experiments are incomplete, refers to facts that caused an interruption of his tests, and expresses the hope that he will be able at some time to take them up again.]

We will now consider our subject in a more scientific and less practical point of view; with regard to the aspect and condition of the surfaces of rupture of the metals broken during our tests.

In most cases one or more spots of fine grain were observed upon the surface, showing the places where rupture first occurred. The broken surfaces of iron and steel were often marked by a dark spot; in other cases there was a smooth, fine grained spot, and in steel and bronze this was the centre of a set of radiating lines. This formed an elliptical surface, which, in Firth steel, had an oil-like smoothness and a lustre under oblique light; while the rest of the surface was rough. In Krupp's steel the elliptical surface is dull and close grained, the rest being crystalline and bright. The ellipse of phosphorbronze is yellower, and the remainder is dark brown in color.

Fracture generally began on the tension side near a corner; but sometimes near the middle.

RECENT DEVELOPMENTS IN THE TECHNOLOGY OF IRON—THE FORM OF THE FURNACE.

From "Iron."

The question of the best form for the interior of the blast-furnace has not of late years occupied so prominent a place in metallurgical discussions as it deserves. The eager debates on the relative advantages of hot and superheated blast and monster and medium furnaces have, so far exhausted these topics, till fresh material for argument has been furnished by further experience. The contour and construction of the furnace is, however, a matter of almost equal importance as affecting the economy of manufacture, while the remarkable variation in practice on this point shows the need of doing something towards reconciling practice with theory. At the present time not only does almost every country affect a form of furnace differing in essential particulars from that improved by its neighbors, but in the same district furnaces working on the same materials frequently present widely different types. It is true that an absolute uniformity of practice is manifestly impossible of attainment, as the "lines" best suited to a particular ore and fuel would be quite inapplicable under other conditions, but, nevertheless, certain guiding principles are of general application. Cylindrical, barrel-shaped, conical, parabolic and elliptical furnaces—furnaces with high angles, furnaces with low angles and furnaces with no angles—cannot all be alike correct in principle, nor equally advantageous in practice.

The foundation of all improvements

in furnace-construction was unquestionably laid by Mr. Gibbons, who had the shrewdness to decipher the lesson "which a fiery finger had written on the walls of his furnaces." In other words, he perceived that, by adopting in the first instance the contour which experience showed would ultimately be shaped out by the action of the heated materials, whatever the original form, he should obtain at once those economical results which old furnaces generally give, but which otherwise would only be obtained after years or months of uneconomical working. And it is excellent testimony to the acuteness of this keen observer and quaint commentator, that the interpretation which he placed on the phenomena he recorded has hardly been modified in any material particular, while the best advice that could be given to furnace designers would be to study their art in the same school.

There are, however, certain preliminary considerations which should guide us in designing the best construction for a furnace, and which assist in rightly applying the information given by the eroded sections of an old furnace. Thus, the dimensions of the hearth should bear such a relation to those of the stack that smelting and reduction may proceed *pari passu*, allowance being made for the possible need of a special allowance for carburization. Then the curves or angles should be such as to offer the least possible frictional resistance to the descent of the charge—if scaffoldings and slips and their attendent evils are to be avoided. Nor should the boshes be so wide as to allow any part of the charge to lie out of the direct current of the gases. Very important is it that the gases should ascend in a regular column, spreading equally through the whole section of the stack, and not escape more rapidly at the sides than at the centre, as they very often do. Some metallurgists insist that the mixture of the elements of the charge should be promoted by the inclination of the furnace walls, while others regard the descent of the charge in parallel horizontal layers as of equal importance. The influence of the width of the furnace mouth is to be carefully considered as affecting the distribution of the charge, the escape of the gases and the reverberation of heat downwards. The mode of charging and taking off the gases, the proper thickness and best way of preserving the walls, and the most convenient mode of tapping slag and metal, are outlying branches of the subject which are well deserving of attention.

When Mr. Gibbons commenced his investigations, some forty years ago, the angle of the boshes in Staffordshire, as on the Continent, was usually laid at so small an inclination that the greatest obstruction was thereby offered to the descent of the materials into the hearth. The hearth itself was generally so narrow (2 or 3 feet square) that fusion could only proceed very slowly. The result was that a column of reduced ore would be retained in the stack long after the gases had ceased to have any further effect on it, simply because its progress towards the crucible was impeded by friction and the inadequacy of the hearth-space. It was therefore inevitable that there should be an enormous waste of fuel. Now, after some six months or a year's working, it was found that the boshes and hearth were worn away to a very great extent, so that the hearth had assumed a circular form and the angle between the boshes and the hearth was nearly obliterated, and it was only after this that the furnace began to do its best work. The enlargement of the hearth, even to the limited extent of an increase from 3 to 4 feet in diameter and increasing the elevation, and therefore the slope, of the boshes, was followed by the best results. At the present time hearths of 7 and 8 feet diameter are common, while in some instances, as at Ormesby, 10 feet has been reached. In Scotland also, as a rule, wide hearths prevail. The circular form, which the fire in any case cuts out for itself, has also been almost universally adopted. The question then arises, can hearths be too wide; or, at least, have we reached in practice the greatest profitable dimensions? Mr. Forbes is of opinion that an increase in the capacity of the hearth would, in many cases at least, be beneficial. Continental practice, however, does not favor wide hearths, and Gruner believes that Cleveland has gone too far in this direction. This metallurgist advocates the use of high and narrow hearths; and would extend his objection

to broad hearths to those of copper and lead smelting blast-furnaces, in which Mr. Forbes found wide hearths were particularly beneficial. Now, there can be no doubt that, with ordinary furnaces, a very wide hearth will sometimes cause trouble ; as, if a slip of unfused material takes place into the hearth, it is hard to get rid of it by concentrating the blast upon it. So, with very infusible ores, the concentrated heat of a narrow hearth, which also keeps the charge longer in the fusion zone above the hearth, may be very useful, unless we have a super-heated blast at command. In charcoal-furnaces, also, the limit beyond which it is inexpedient to widen the hearth is soon reached. But most of the alleged difficulties with wide hearths are due to insufficient and ill-distributed blast-power. With plenty of blast—not necessarily at a great pressure—and a sufficient number of tuyeres, a wide hearth need give no trouble, while it renders it more easy to give the boshes their proper inclination. Even with refactory ores, by using a sufficiently heated blast, it is easy to keep the temperature as high as is necessary ; it is, however, for fusible mixtures that ample fusion-space is most useful. For coal-burning furnaces, as Wedding has pointed out, a wide hearth is always desirable ; hence their adoption in Scotland. The same may be said when dealing with silicious ores and hot blast if the quality of the pig is to be preserved. In the yearly increasing industry of spiegel-making, in which a high temperature is very important, the advantages of a large hearth capacity are generally admitted. It need hardly be said that the question of the proper dimensions of the hearth must, after all, always be mainly decided by the special circumstances of each furnace, such as the quality of ore and fuel available, the quality of pig it is desired to produce, and the temperature and volume of blast available. Yet, subject to these restrictions, there are not wanting indications that an increase of hearth-area might in many cases be advantageously introduced, especially if, by the use of an increased number of tuyeres, the foci of vigorous combustion which surround each tuyere are regularly distributed over the whole space, and when fusible mixtures are operated on.

We have seen that one of the effects of the shaping action of fire and friction on the interior of a furnace, as observed by Gibbons, is to plane away and round off, to a great extent, the sharp angles between the hearth and the body of the furnace. A good example of this action is shown in a section of the interior of an Austrian charcoal-furnace at Mariasgell after a campaign of several years. This furnace was giving, at the time it was blown out, results superior to any it had before attained ; and we find that it then had almost obliterated the bosh and hearth angles, and assumed a shape not unlike the continuous curve of certain Belgian and modern Staffordshire stacks. Weniger goes so far as to say that the consumption of fuel with very flat bosh-angles will be nearly double that which would be necessary with the most favorable inclination. Parry says an angle of 70 deg. is the most advantageous, while on the Continent an inclination of only 40 deg. is not uncommon. It is believed that the difficulties and unsatisfactory results which were recently encountered with certain of the monster furnaces in Cleveland were mainly due to a want of attention to this particular. The very considerable pressure exerted by the lofty columns of materials in a modern stack renders it particularly desirable to confine its thrust as far as possible to a lateral direction.

If the course of a mixed charge of fuel, flux and ore is followed from the throat of the furnace downwards, it will be seen that till it approaches the zone of incipient fusion its bulk will not be materially altered, except by the compressive action of the superincumbent mass and the gradual removal of a portion of the fuel as carbonic oxyde. This will be most conspicuously the case when the ore has been calcined, and the fuel coked, prior to its introduction. The right form for the shaft of the structure would seem therefore to be a section very gradually diminishing from the throat to the boshes, and thence rapidly contracting to the crucible. But we find that many furnaces *expand* from the top to the boshes, the enlargement being in some cases, especially in charcoal furnaces, very marked. In other cases we find cylindrical stacks, this pattern, or a near approach to it,

having found much favor in Scotland and elsewhere since its introduction fifty years ago.

It is generally assumed that the expansion of the furnace downwards is of advantage in diminishing the resistance to the descent of the materials. But both the fact and the advantage are exaggerated. The downward pressure of the column of materials is, if not greater, at least more regular in the cylindrical stack, and this is of great effect in preventing the formation of obstructions and promoting a regular descent. Moreover, a rapid descent through the stack implies a prolonged sojourn in the highly heated space about the boshes ; for it is found that the total time occupied by a charge in passing through a conical furnace is not less than that occupied in other forms of furnace. Now we have seen that it is in the comparatively cool region of the stack that reduction takes place most economically ; and it is also to be observed that it is in the lower region of the furnace that the metal takes up those bodies—such as phosphorus, sulphur and silicon—which are most deleterious to its quality. Any time, therefore, which the metal spends in the region immediately above the hearth, beyond the period absolutely necessary for carburation and preparatory fusion, is distinctly prejudicial ; while the longer time it spends in the relatively cool regions of the stack, where $CO_2 + C = {}_2CO$ reaction is mimimized, the more economical will be the result. It may be inferred, also, that in the tall furnaces now in use, carburation commences much sooner than in the old form, and that therefore the only justification for the narrow stack and wide boshes—namely, the expediency of producing a highly-carburized pig—is removed. Any considerable widening from the top downwards has also a tendency to promote accumulation of materials at the angle formed by the junction of the boshes and shaft, and hinders an equably diffused up-flow of the gases. But so great and, indeed, well-founded, is the apprehension of irregularities and scaffoldings entertained by ironmasters, that any alteration of a mode of construction which has the reputation of preventing their occurrence would be only very cautiously adopted. Yet we are not aware that either the so-called cylindrical furnaces, or those Staffordshire furnaces, which, like Gibbons' improved pattern, begin to taper downwards from a point more than halfway up the furnace, are particularly subject to this drawback.

The enlargement of the upper part of the furnace "by scooping it outwards," which Gibbons considered of the highest importance, has been advocated with great ability and particularity by Mr. Parry, of Ebbw Vale, and, at his instance, many South-Welsh furnaces have adopted the dome-shaped stack which he recommends. Though it is doubtful whether so little action takes place in the upper part of the furnace as Gibbons imagined, it is probable that, with low furnaces and friable fuel, and such ores as those of Staffordshire and South Wales, the dome shape has certain advantages which justify its adoption. A great capacity for a given height, and the accumulation of heat in the stack are perhaps its most obvious features. According to Parry's formula, the depth from the widest part to the tuyeres should not be less than the diameter at the widest part *plus* half the diameter at the tuyere-level. He also gives minute directions for the proper curve to be adopted from the top of the boshes to the mouth.

In the Rachette Furnace, which expands continuously from the hearth to the top, there is presented the most extreme contrast to the conventional type. This mode of construction presents, theoretically, certain decided advantages—the extreme division and regular distribution of the blast, among others—yet, notwithstanding the favorable accounts of its work given some years ago, it appears to have quietly dropped into the ranks of exploded ideas as regards its application in the metallurgy of iron. It remains to be seen, however, whether a modification of the principle may not still do good service ; and it is worthy of remark that in Germany, and notably in the United States, the Rachette principle, both in its integrity, and as modified by Piltz, works admirably in lead smelting. Truran, of Dowlais, proposed a mode of construction similar to that adopted by Rachette, many years ago, and pointed out that a progressive in-

crease in diameter, from the hearth upwards, would secure a more uniform descent of the charges, and, as we shall show later, both by presenting a minimum resistance to the passage of the blast, and otherwise, facilitate the operations of the furnace. It would, however, be in remote districts, where high furnaces and powerful blast apparatus are so costly as to be practically inapplicable, that this type of construction would have the most success.

An elliptical section, the application of which to blast-furnaces was patented by Algers twenty years ago, presents, in common with Rachette's oblong section, the advantage of allowing the charges to sink uniformly through the stack, and, as Dr. Percy has pointed out, renders it comparatively easy for the blast to reach the centre of the furnace however large its dimensions. A small elliptical charcoal-furnace in Massachusetts, 33 feet high, appears, according to recent accounts, to give very good results, considering its small size. On the other hand, a circular shape offers less external area for a given capacity than any other shape. That this is important, as affecting both economy of construction and loss of heat by radiation, is obvious. As the introductiton of elliptical furnaces was inaugurated with anticipations of the most glowing kind, not altogether unsupported by scientific metallurgists, it would be of interest if any our readers were to contribute any facts bearing on their subsequent history.

It may here be suggested that advantage might be taken of the forthcoming Exhibition at Philadelphia to secure much valuable information, which it would be beyond the power of any individual, or even an association, to obtain at any other time, but which, once collected, would be of the greatest service to metallurgical industry. Though some may still cling to the selfish policy of retaining and jealously guarding, as so-called *trade secrets*, all information derived from their daily technical experience, it is generally perceived that by such hoarding more is lost than gained. It is not, even now, too late for the Commissioners of England, Germany, France and Austria, in conjunction with the American Centennial authorities, to invite by circular the leading metallurgical firms of their respective countries to furnish in a specified form, such detailed particulars, illustrated as far as possible by plans, of the working of the plant and processes under their control, as they may feel disposed to give. Such information from reliable sources would at once set at rest many vexed questions, which would otherwise only be tardily solved at an enormous cost of unproductive labor and wasted material. That we ourselves have much to learn from the best Continental and American practice, is not less true than that in many points we are in advance of our neighbors. Not the least important feature in such a programme would be the collection of a series of internal sections of blast-furnaces blown out for repairs or other causes (of which there are unfortunately just now only too many). Accompanying these fire-shaped sections would be drawings of the original contour, with full details of the charges used, and the working immediately before the stoppage, and at different periods of the campaign. Such returns would form a solid basis for subsequent progress, and would materially advance that which should be the leading object of a true *world show*—the growth of technical knowledge. Failing its adoption by official representatives, we commend the idea to such bodies as the various Societies of Engineers, the American Institute of Mining Engineers, and our own Iron and Steel Institute.

An explosion lately occurred at the works of Messrs. Cammell & Co., of Sheffield. In one of their Bessemer furnaces the men were on the point of pouring molten metal into moulds when the spindle of the vessel broke and the large cauldron heaved entirely over. The metal fell into the pit, and coming in contact with some water, exploded with a terrific report. Two of the workmen had a narrow escape of their lives, having barely time to get out of the pit before the explosion occurred. The roof of the furnace was partly blown away, and a quantity of clothes belonging to melters was destroyed. The report was heard nearly a mile off.

—*The Engineer.*

NOTES ON CONCRETE.*

From "The Architect."

At one time I had under consideration the cheapest method of covering a large tank or reservoir, and it occurred to me that the construction of parallel partition walls, carrying thin concrete arches, would probably be the best solution of the question. As it would be desirable in such a case that the roof of the reservoir should be covered with about 2 feet of earth, it became a question what the minimum working thickness at the crown of such an arch should be. Apparently this was a matter of calculation, to be calculated in a few minutes, with the assistance of tables giving the ultimate strength, under compression, of concrete; or, better still, by the aid of the results of Mr. Grant's experiments on concrete blocks of various materials and various proportions of cement.

Having the opportunity I made the following few experiments, which, as such, are very incomplete, but must be, to a certain extent, interesting, as the results greatly surprised those engineers who witnessed them.

As has been said above, the breaking load of a concrete arch is readily calculated, the crushing weight of the material being given, and in a most carefully made arch—say one constructed under the immediate eye and personal superintendence of the engineer himself—the result, as calculated, might be obtained. I, however, wished to see how such a result would be affected by the superintendence not being special, the materials not specially selected, and the labor not specially skilled—in fact, to ascertain the additional factor to be applied under such circumstances.

The arches which were constructed for these experiments were four in number, all of the same dimensions exactly—namely the width was 1 foot, the span 12 feet, the rise 12 inches, the thickness at the abutments 6 inches, and at the crown 2 inches The cement was Portland, and the sand and gravel mixed as they came from the pit, and not particularly clean. The cement used was, unfortunately, not tested, but as several tests for tension were made, before and after these experiments, of cement from the same yard, it may be assumed that it was of fair average quality.

The concrete in No. 1 arch was composed of 1 part of cement to 4 parts of gravel and sand; in No. 2, 1 of cement to 6 of gravel and sand; in No. 3, 1 of cement to 7 of gravel and sand; and in No. 4, 1 of cement to 8 of gravel and sand.

The experiments were as follows:

No. 1 arch was made on August 14 and broken on December 14. The load consisted of fire-bricks carefully added (in laying each course) by equal numbers from each abutment to the crown. Care was taken, as the courses grew up, that the bricks over the crown should not touch longitudinally. A number of bricks were weighed at different times, from which the average weight was deduced. On December 15 the number of courses built up was 10, the number of bricks 556, and the load 4,059 lbs. On the 16th 4 courses were added, bringing the weight up to 5,468 lbs. On the 18th 2 courses were added; on the 21st 4 more courses, and on the 22d 4 more courses were added; and then, while more bricks were being sent for, the arch failed under 25 courses ($1\frac{1}{2}$ brick thick), consisting of 1,221 bricks, and weighing 9,052 lbs., or a uniformly distributed load of $754\frac{1}{2}$ lbs. per square foot of roadway. If to this be added the dead load, the breaking weight is found to be 9,521 lbs. = 4 tons 5 cwt. Assuming the curve of pressure to pass through the middle of the crown and each abutment, the horizontal thrust of the unloaded arch was 654 lbs., or 27 lbs. per square inch of section. At the time of breaking, the horizontal thrust was 17,104 lbs., or 713 lbs. per square inch of section.

Unfortunately, at the termination of the first experiments, the bricks which were loosely built up on the concrete arch until they constituted a breaking load, and to a height of 6 feet, in their fall came suddenly on arch No. 2, and fractured it.

* "Notes on Concrete, and on some Experiments with Concrete Arches." By Charles P. Cotton, Past President. Read at a meeting of Institution of Civil Engineers of Ireland.

Arch No. 3 was built on September 9, and broken on December 30. On December 28 it was loaded with 6 courses of bricks, 1½ brick thick. On the 29th 5 more courses were added, and on the 30th the arch gave way when 8 more courses had been added, making a total of 17 courses, consisting of 843 bricks, estimated at 6,070 lbs, or 506 lbs. per superficial foot of roadway. Adding to the above the dead weight of the arch, the breaking weight is found to be 6,539 lbs. When 6 courses of bricks were on, a deflection of half an inch at the crown was observed, which gradually increased to 1 inch on the 16th or last course but one.

Arch No. 4 was built on September 10, 1875, and broken on January 3, 1876. This arch, the composition of which was 1 in 8, seems to have been better put together than the last, which was 1 in 7, for it carried a heavier load before breaking. At the 8th course a slight deflection, about ⅛ inch, was observed, which on the 17th course increased to ½ inch, and on the 20th and final one to 1 inch. The way in which the arch ultimately failed took me by surprise. After the 20th course was added, it was noticed that the arch was giving way, by seeing the deflection slowly but gradually increasing, until the final rupture several minutes, probably about five minutes, afterwards. This fact and the gradual nature of the increase of deflection was plainly observed, owing to the way the bricks were built up so as to leave a clear vertical space of 2 inches over the crown. As the height of the bricks was, roughly, 4 feet 6 inches, the gradual nature of the subsidence was indicated by the slow approach of the top bricks on either side of this vertical space. The total number of bricks in the 20 courses was 911, estimated at 6,559 lbs., or a live load of 547 lbs. per square foot of roadway. If to this be added the dead weight of the arch, it amounts to a total of 7,028 lbs., the horizontal thrust from which is 12,800 lbs., or 534 lbs. per square inch of section of arch at the crown. As the weight of 2 feet of clay may be taken as 240 lbs. per superficial foot of the tank, it is clear that a very small addition to the thickness of this arch would bring it within a sufficient factor of safety.

It is a common observation to make that it is an error in design to apply concrete in the form of an arch at all, and that its true position in work is to supply, as far as possible, the place of a solid stone slab of the same size, but I do not think that its use should be so restricted. It is, of course, admitted that to employ concrete in an arched form, where full resistance to the horizontal thrust is not provided, is false design, except the arched soffit be required for other reasons, for in that case the mass of concrete can only act as a girder. As girders or bressummers, concrete beams have been employed, even to the extent, I believe, of reducing the depth of the concrete beam to one-twelfth of the span of the ope.

There are, in my opinion, many cases where concrete can be used in arches with advantage in the nature and economy of the work—in arches over windows and doors, and relieving arches over large opes, where there is a good length of wall on each side, and in small road bridges in certain places, for instance in out-of-the-way places in buildings where bricks are not to be had, and for bridges over mountain streams, where the cleanest gravel is most probably on the spot.

The resistance afforded by the abutments or walls on either side of the arches must be fully equal to that required to resist the horizontal thrust, as will generally be the case in house-building, and in bridges it must be supplied by the proper thickness of abutments. But it must not be supposed that thicker abutments are required for a concrete arch than for a stone one; the thrust of a stone arch would not be increased by the joints being petrified and making one mass with the arch-stones.

Road arches have been so constructed on the property of Mr. Richard Mahony, Dromore Castle, in the county of Kerry, under the superintendence of Mr. M'Clure, who has kindly furnished me with the particulars of these and other concrete structures on the same estate.

Mr. M'Clure writes:—"The last bridge built in 1873 is on a rapid mountain river. The abutments were built of stone, owing to the wetness of the season and the consequent danger of floods

carrying away the necessary framing for the formation of concrete piers. The arch of this bridge was completed in ten working hours by fifteen laborers and one carpenter, who had, in the same time, to wash and prepare gravel found on the spot. The dimensions of the arch are 18 feet span, 3 feet 6 inches rise, 2 feet 6 inches thick at the springing, and 1 foot 6 inches at the crown. Large stones were cast into the concrete, pressed down without any regard to regularity of position. These bridges are almost as hard as the hardest stone, and, I believe stronger than a stone bridge could be. The centres were not removed for two months"

Mr. M' Clure gives some further particulars of other concrete works on Mr. Mahony's estate as follows :

"The proportions we have used on this estate for buildings, such as farm houses, laborers' cottages, and farm-buildings, were 1 measure of Portland cement to 8 parts of well-washed sand and gravel from the bed of a river, and passed through a screen with bars 1 inch apart. The proportions used in building bridges were 1 part of Portland cement to 7 of clean river or sea gravel. Large stones are used—the roughest stones suit best—about 40 per cent. of split stone can be used safely in building concrete walls. I have used 25 per cent. in bridges. Any shape of stones can be used. In the case of buildings, the stone, or what we might call 'packing stuff,' should be placed about four inches to 6 inches apart, and should be at least 3 inches narrower than the thickness of walls, so as to form a band of concrete all around. Pressure should be applied. We have simply, in the case of house-building, packed the stuff tightly into the apparatus with wooden blocks about 2 feet long, pressing the concrete into every joint between the stones used for building the walls The dimensions for all cottage walls on this estate are 9 inches thick ; chimney walls, 18 inches ; partitions, 4 inches. I have built a large steading (which cost over £2,000) of concrete. The walls in some cases are 18 feet high, and 12 inches thick ; also a garden wall, over a quarter of a mile long, 11 feet high, and 9 inches thick ; a cistern, 5 feet high, 6 feet by 5 feet, walls 9 inches thick ; a loose horse-box, walls 14 inches thick, with a cistern over, resting on a concrete roof, capable of holding eight tons of water, and which is perfectly staunch.

The chief advantages of concrete-building are rapidity and economy. If it were more generally understood it would be largely used for buildings and bridges. I calculate at present prices (December 1874), where gravel of a suitable description can be got within two miles of the work, the cost of a cubic yard of concrete will be from 12*s*. to 15*s*.

Adie's testing machine is expensive, the cost of even the smallest being £20, which places it beyond the reach of small consumers. I believe the consumer must depend very much on the character and standing of the manufacturer to get a pure article, just as one has to depend on the character and position of a druggist to make up a medical prescription. I have found that cement kept dry for six or nine months before being used sets much more slowly than fresh cement, but forms harder concrete, almost as hard as a rock."

I have also learned that Mr. N. Jackson, C. E., who has charge of the West Riding of Cork, has built several bridges in concrete, using one part of cement, by measure, to six or even eight of clean, sharp sand and gravel, packing the piers and abutments with large stones, well rammed. Mr. Jackson finds that concrete answers remarkably well for country road bridges, especially economical in the case of skew bridges. I have also noticed, as a good instance of the application of concrete to railway works, the formation of a turn table centre-piece bed and sides, all in concrete, on a railway embankment (consequently on made ground) erected by Mr. W. A. Scott, near Mallow Station.

Lately, by permission of the engineer, the president, Mr. W. W. Willcocks, vice-presidents, R. M. Bancroft and G. I. Morrison, and a number of members of the Civil and Mechanical Engineers' Society and friends, visited the works of the London and North-Western Railway widening, Chalk Farm, the tunnel now in course of construction being the chief centre of interest.

RELATIONS OF HEAT WHEN MOIST FUEL IS USED IN GAS FURNACES.

By RICHARD AKERMAN, Stockholm School of Mines.

From "Iron."

When fuel containing water is burned, the water may simply be converted into steam, or the steam may be decomposed by contact with red-hot charcoal, hydrogen and carbonic oxide being set free. If we suppose the fuel to have a temperature of 5 deg. C., which nearly corresponds to the mean temperature of the middle part of Sweden, there are required for every weight-unit of water which is vaporized from the fuel, $95+536=631$ heat units, to which there comes to be added the heat which the watery vapor formed carries with it when it escapes from the furnace by its being heated above 100 deg. C. But as this naturally depends on the temperature at which the gases leave the furnace, it must be very different in the case of different furnaces, even if we confine ourselves, as is our intention at present, to gas re-heating furnaces.

In order to be able to estimate correctly the quantity of heat lost with the watery vapor, we ought, in the case of such furnaces, to ascertain both the temperature which the gases have when they pass out of the fire-place or generator, and that of the final products of combustion when they escape from the furnace itself. The temperature of the gases passing out of the fire-place or generator is, however, so extremely variable, according as different kinds of fuel and different constructions of generators are employed, that it may perhaps be regarded as impossible to fix upon any mean temperature which would be generally applicable with any tolerable approach to accuracy. A knowledge of this is not, however, for the object of this paper of any very great importance, on which account we shall, for the present, leave it aside, and confine ourselves to the temperature at which the products of combustion leave the furnace. This, perhaps, in our common "Koltorn" re-heating furnaces, with only a moderate extent of heating space, may be estimated at 600 deg. C., and as the specific heat of watery vapor may be taken at 0.475, the furnace, with every weight-unit of watery vapor to be found in the products of combustion, is derived not only of the 631 heat-units enumerated above, but also of $600\times0.475=\underline{284}$ heat-units.

But besides this true loss of heat of about 900 heat-units for every weight-unit of water, the watery vapor occurring in the gases also occasions the very considerable inconvenience that, as the specific heat of the watery vapor is about twice as great as that of the other gases, the temperature of the products of combustion is reduced by its presence to a greater extent than would be caused merely in consequence of the loss of heat occasioned by the watery vapor. Finally, the watery vapor in a re-heating furnace is detrimental, inasmuch as it has an oxidizing action on the iron, the loss of which, by burning, is therefore increased by its presence.

The reasons why, when a fuel abounding in water is used and a very high temperature is desired, it is *necessary*, and, even when a comparatively moderate temperature is to be reached, *desirable* to employ the Siemens-Lundin principle, are accordingly evident. For in this way both the inconveniences connected with the presence of watery vapor completely disappear, inasmuch as the watery vapor is removed before the gases enter the furnance, and even the loss of heat caused by the over-heating of the watery vapor may be reduced to nothing if the generator is properly constructed; for if the gases, before they leave the generator, are made to pass through a sufficiently deep layer of fuel, their temperature need not exceed 100 deg. C., and the whole loss occasioned by the vaporizing of the water may, therefore, in this case, be limited to 631 heat-units per weight-unit of steam occurring in the gases.

In order, under such circumstances, to vaporize a weight-unit of water there is thus required, when the carbon, as is desired in a gas-generator, is burned only

to carbonic oxide, 631 : 2473 = 0.255 weight-unit of carbon; and the water contained in the fuel cannot, therefore, exceed 2473 : 631 = 3.92 times the weight of the carbon, even if dryer fuel is used for the first firing, and no loss of heat is supposed to take place through the walls of the generator. But as it is impossible to prevent loss of heat through the walls of a furnace in action, the content of water in a moist fuel intended for generating gas can scarcely exceed about 3.7 times the weight of the carbon occurring in it, and when such fuel is used, it is necessary, in addition, tô mix a dryer with it in the beginning until the necessary temperature has been reached in the furnace.

If we proceed now to consider the relations of heat which exist when the water is decomposed in the fire-place by red-hot carbon to hydrogen and carbonic oxide, we find that the fire-place or generator thereby loses yet more heat, for besides the 631 heat-units consumed in producing steam, there are in this case required 29638 : 9 = 3293 heat units;* but it is yet of great importance in the case of gas-furnaces, especially when they are not provided with condensers on the Siemens-Lundin principle, to get the watery vapor decomposed in this way as completely as possible, for the hydrogen thus formed gives back, when burned in the re-heating furnace itself, the same quantity of heat 3293 units, and this development of heat takes place just at the place where the high temperature is desirable, while, on the contrary, the loss of heat went on in the fire-place or generator, where no very high temperature is required for any other purpose than the decomposition of the watery vapor now in question. For this a very high temperature in the generator is necessary, for if it is not high enough the watery vapor is not decomposed, wherefore, also, this relation may in this respect be said to regulate itself.

The reason of this, again, is that the decomposition in question must take place through red-hot carbon, and the thicker the layer of this which is passed through by the steam which is formed, the more complete is the conversion into carbonic oxide and hydrogen; but, inasmuch as this decomposition is attended, as we have seen, with a considerable diminution of heat, it is clear that if the layer of fuel, through which the gases formed in the generator must pass, is thick, the red-hot or active part of it must be thinner in the same proportion as the content of water in the fuel is greater, and the thinner the red-hot stratum of fuel is the less steam is decomposed in its passage through it.

If the red-hot stratum of fuel becomes too thin by the diminution of heat occasioned by a large content of water, little or no water can be decomposed in this way, but the combustion comes to go on chiefly in the way first described with a less consumption of heat in the generator; but the stratum of red-hot fuel which the gases pass through may also easily in such circumstances be so thin that none of the carbonic acid formed during the combustion is reduced to carbonic oxide. As, however, the carbonic acid is incapable of further combustion, the carbon oxidized in this way in the generator in common "Koltorn" furnaces, is of little, and in Siemens-Lundin furnaces of no use for the re-heating itself, and when the combustion goes on in this way to a considerable extent, no proper heat can be obtained in the re-heating furnace.

If we calculate how many weight-units of carbon must be burned to carbonic oxide in order to develop the quantity of heat which a weight-unit of water occurring in the fuel requires for its decomposition in the way just described, we find it to be (3293 + 631) : 2473 = 1.587 weight-unit, which corresponds to a content of chemically combined and hydroscopic water, amounting to 63 per cent. of the carbon existing in the fuel; but, in fact, if the whole content of water is to be decomposed the fuel used in a gas-furnace cannot contain nearly so much water, for even if the requisite temperature is in the beginning attained by using a drier fuel, so that it has only to be kept up afterwards with the moist fuel, there is always a deal of heat lost through the walls of the fire-place, and

* Properly speaking, there are consumed in this case only (29638—6×2473) : 9 = 1644 heat units, inasmuch as, for every equivalent of water decomposed by carbon, there is developed as much heat as an equivalent of carbon can give out when burned to carbonic oxide; but this deduction ought not to be made here, for if the carbon had not been oxidized with water it would, instead, have been burned with air, and it had thus come to develop the same quantity of heat without the water.

on this account the water contained in the fuel, if it is to be completely decomposed, may certainly not exceed a little over 50, say 55, per cent. of the weight of the carbon.

Let us now see how the different sorts of fuel correspond to these requirements.

Dry and well carbonized *charcoal* may be taken as containing 82 per cent. carbon and 10 per cent. hydroscopic water, and the relation of weight between the water and carbon is then about 10 : 82, the water being 12.2 per cent. of the carbon.

Ordinary *pit coal* may perhaps be reckoned to contain 81 per cent. carbon and 9 per cent. chemically-combined water, the relation of weight between the water and the carbon in it being thus about 14 : 81, the water being 17.3 per cent. of the carbon.

Peat is more variable in its composition than coal, and it is therefore difficult to state any true average for its constituents; but if we confine ourselves to good peat, perhaps we may take it as consisting, after complete desiccation, at 110 deg. C., of about 57 per cent. carbon, and 2 per cent. hydrogen, 36 per cent. chemically-combined water, and 5 per cent. ashes. In only air-dried peat there are found from 20 to 40 and even 50 per cent. hydroscopic water, and it may therefore be taken to contain 40 per cent. carbon, 25 per cent. chemically-combined, and 30 per cent. hydroscopic water. The relation of weight between the water and carbon is thus, in thoroughly desiccated good peat, 36 : 57, the water being 63.1 per cent. of the weight of the carbon, and in air-dried peat 55 : 40, the water being 137.5 per cent. of the weight of the carbon.

Wood completely dried at 120 deg. C. contains about as much water as carbon. Air-dried wood contains besides about 20 per cent. hydroscopic water, and it may thus be taken to consist of 40 per cent. carbon, 40 per cent. chemically-combined and 20 per cent. hydroscopic water. Newly-felled and little-dried wood contains, on the contrary, 50 per cent. hydroscopic water, and upwards, and its composition may therefore be taken to be 25 per cent. carbon, 25 per cent. chemically-combined and 50 per cent. hydroscopic water. The relation of weight between water and carbon is thus, in thoroughly furnace-dried wood, 50 : 50, the water being 100 per cent. of the carbon; in thoroughly air-dried wood, 60 : 40, the water being 150 per cent. of the carbon; and in newly-felled wood, 75 : 25, the water being 300 per cent. of the carbon.

Sawdust, which has been air-dried by self-heating in a proper sawdust house, contains 27 to 30 per cent. hydroscopic water, while fresh sawdust, on the contrary, commonly contains 50 per cent. hydroscopic water; but sawdust can also be found that contains 60 per cent. The relations of weight between the water and the carbon is thus, in the three varieties above enumerated, 64 : 36, 75 : 25 and 80 : 20, the water being in the first 177 per cent., in the second 300 per cent., and in the third 400 per cent. of the weight of the carbon.

It has been pointed out that, if a fuel containing water is to be burned in such a way that its steam is completely decomposed, and carbonic oxide and hydrogen set free, the water contained must not exceed 55 per cent. of the weight of the carbon. Of the sorts of fuel above enumerated, however, charcoal and pit coal are the only ones whose content of water does not go up to this amount; but, as far as charcoal is concerned, it happens, unfortunately, too often, that it is so moist that its content of water exceeds 55 per cent. of the weight of the carbon.

As the water contained in air-dried peat amounts to 137.5 per cent., and in air-dried wood to 150 per cent. of the weight of the carbon, it is natural that neither of these kinds of fuel, and still less undried wood, which contains three times as much water as carbon, is fit for being used alone in such gas-furnaces as are not provided with condensers, but when they are used in this way, they ought to be mixed with charcoal or pit coal, as is generally done. Thoroughly desiccated wood and, still better, peat, are indeed in a much superior position in this respect, the former containing 100 and the latter about 63 of water per 100 of carbon; but even thoroughly desiccated peat of good quality does not permit the complete decomposition of the water to take place unless it is mixed with some fuel containing less water.

If the per centages of carbon and

water in different varieties of fuel are known, it is naturally easy to ascertain how much of a fuel containing little water must be added to one containing much, in order that the whole content of water may be decomposed in a proper generator. Supposing the contents of carbon and water in the different kinds of fuel to be as stated above, these proportions, *reckoned by weight*, are the following:

15.9 % charcoal with 84.1 % furnace-dried peat.
17.7 % pitcoal with 82.3 % furnace-dried peat.
51.3 % charcoal with 48.7 % furnace-dried wood.
54.4 % pitcoal with 45.6 % furnace-dried wood.
65.8 % charcoal with 34.2 % air-dried peat.
68.6 % pitcoal with 31.4 % air-dried peat.
68.9 % charcoal with 31.1 % air-dried wood.
71.7 % pitcoal with 28.3 % air-dried wood.
84.8 % charcoal with 15.2 % undried wood.
86.7 % pitcoal with 13.3 % undried wood.

These figures, however, denote merely the greatest proportion of weight in which the above-mentioned fuels, rich in water, may be mixed with fuels containing a smaller proportion, if the whole of the water is to be decomposed during combustion in a properly-constructed generator; or, in other words, if the moist fuel is to be utilized in the most advantageous way possible without condensing the water; but it is clear that there is nothing to prevent a smaller proportion of the moist fuel to be used than is stated above; and it may also sometimes be advantageous, if not in a technical, at least in an economical respect, to allow the moist fuel to enter into the mixture in a somewhat greater proportion than is given above; if, for instance, the difference of price between the moist and the dry fuels is greater than the difference of their true values as fuels. But in this case it ought to be kept in view that the moist fuel could be utilized more advantageously by being burned in a furnace on the Siemens-Lundin principle, for when the mixture of fuels contains so much water that a considerable proportion of it cannot be decomposed even when the generator is properly constructed there is good ground for placing between the generator and the furnace itself a condenser, but it is then clear that it is necessary to employ regenerators for again heating the gas. It is also to a considerable extent on this account that the consumption even of furnace-dried wood in an Ekman wood re-heating furnace is so much greater than the quantity of only air-dried wood in a Siemens-Lundin furnace, that for every centner of bar iron reheated in the former 5 cubic feet furnace dried wood are required, and in the latter 3½ to 4 cubic feet wood merely air-dried.

When the water, as in a Siemens-Lundin furnace, does not require to be decomposed, fuel can be used, as we have already pointed out, which contains so much water that it is 3.7 times the weight of the carbon, and in such a furnace accordingly it suits very well to use common fresh saw-dust, which contains about three times as much water as carbon; but, on the other hand, it does not do, as experience also has shown, to employ alone such dark and particularly moist sawdust, with about 60 per cent. hydroscopic water as sometimes occurs, seeing it contains about four times as much water as carbon.

Such fuel as the last-mentioned cannot naturally come in question for use in the re-heating furnace, if a Lundin furnace is wanting. Even for wood, branches and peat the last-mentioned furnace is the most suitable, but if the supply of such fuel is not sufficient, it can be used in mixture with pit-coal in common "Koltorn" reheating furnaces, as, indeed, is commonly done. If the first-mentioned kinds of fuel are to be used in this way to any considerable extent, it is best, for the reasons already given, to desiccate them thoroughly in the first place, the rather as this can be done in various ways with the help of the heat often escaping otherwise unutilized from hearths and furnaces; and that such moist fuel after thorough desiccation acquires a greatly increased value for use in the "Koltorn" furnace, is best seen from the fact that the furnace-dried "tramp" peat was considered at Bjorneborg to correspond in the "Koltorn" furnace to one and a-half times its bulk of charcoal, while the machine worked but only air-dried "tube" peat from similar mosses is in general only considered equivalent to its own bulk of charcoal, and air-dried "hand" peat is commonly reckoned to have only the value of half its bulk of charcoal, all in "Koltorn" furnaces.

As an instance of a work at which large quantites of undried poor fuel are used in the common "Koltorn" furnace,

and large quantities of peat, &c., are burned up quite unnecessarily, a place may be referred to where, for a considerable time, it was customary to consume per centner rolled bar iron not only 0.434 cubic feet coal, but also at the same 0.492 c. f. "hand" peat not properly air-dried, and 0.548 c. f. refuse wood, while at another work, in quite the same circumstances, there was employed only 0.38 to 0.40 c. f. coal without mixture with any other fuel. It seems to follow from this that the mixture of peat and wood at the first-mentioned place was not only of any use, but instead required some coal to counteract the injurious effect of the great content of water.

I hope, however, that nobody will, in consequence of this statement, understand me as seeking to oppose the employment of peat and other inferior fuel in reheating furnaces; for, on the contrary, my view is that reheating in this country (Sweden) should, for the most part, be carried on with such fuel; but we must either properly dry such fuel, if we wish to mix it in any considerable quantity with coal and employ it in reheating furnaces, or go to the expense of Lundin furnaces if it is used undried.

THE MECHANICAL THEORY OF HEAT.*

Written for VAN NOSTRAND'S MAGAZINE.

An examination of this work satisfies us that it will not only supplement but supplant many of the more recent treatises on this subject. It is a very readable book for scientific persons, and eminently suitable as a text book for advanced students. It has the merit of analytical treatment of the subject in the most complete and satisfactory manner. The style of the author is so happy and engaging that the reader is unconsciously interested, in what, in ordinary words on this subject, are quite dry and uninteresting details. The first part gives the reader a condensed and yet complete synopsis of the history of the investigations in heat, by Huggens, Fresnel, Rumford, Sadi, Carnot, Mayer, Joule, and others, so admirably arranged in matter and composition as to give the reader a sincere pleasure in its perusal. Then follows a clear deduction of the fundamental laws and principles of Dynamics, based upon the General Law of Energy, and the Mechanical Theory of Heat is shown to depend upon this law, and to be indeed but the expression of it so far as it relates to this most interesting branch of Molecular Physics. The author has attempted and indeed accomplished in a most satisfactory manner, in the domain of Heat what we hope to see done in the near future in that of Magnetism and Electricity.

Following the demonstration of the general dynamic laws the reader is at once led to the study of temperatures, quantities and measure of Heat, thermodynamic functions and their discussion, the theoretical determination of Joule's coefficient Absolute Temperatures, and other kindred branches of the subject.

The fundamental laws of the more permanent gases, deduced by experiment, are compared with the theoretical deductions, and are carefully examined in detail; and, by a very simple process, the differences are shown to fall within the limits of probable error of observation, or to be so small as to be neglected.

Clear discussions of the methods of Elimination of Internal Energy, and its application to Steam and air Engines of the Cycles of Carnot—of air engines in general and in particular—of Isodiabatic and Adiabatic Curves, and of lines of transformation, followed by an accurate comparison of the efficiency of Air and Steam Engines, give to the attentive student a most thorough grasp of this ordinarily involved and intricate subject. This is suplemented by a masterly analysis of the most recent investigations made by Rankine, Sir W. Thompson, and other able scientific men who are to-day standard authorities in these matters.

The author has thus happily grouped together in a compact form, the elementary principles of his subject, and deserves the gratitude of every lover of clear

* McCulloch on the Mechanical Theory of Heat and the Steam Engine. In press by D. Van Nostrand.

statement and accurate analysis, no less for these qualities than for the happy faculty he has displayed of creating in his readers an intense and well sustained interest from the first to the last of this book.

As a text book it is admirably adapted to those students who have mastered the Calculus; for although it is a condensed treatise, the discussions are remarkably clear and complete, and so well arranged and connected that there is an orderly progression from the fundamental principles of the science to the most recent developments of the present time.

We welcome this book as being the embodiment of all that such a book should be, and the forerunner of a class of standard works on science of which the scientific men of our country may well be proud.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—Tests of American Iron and Steel.—During the past year, the United States Board appointed to test Iron, Steel and other Metals, under authority of an Act of Congress procured by a committee of the Society, has been organized, has prepared the plans of investigations to be adopted, and has appointed its committees on the several subjects to be studied.

The general plan is announced, and is to be a thoroughly scientific and systematic exploration of the field assigned to the Board. Materials are not only to be tested and the results stated as those derived from the examination of a metal of a conventional denomination, but the test-piece, in each case, will usually be examined to determine how far peculiar qualities are attributable to peculiarities of chemical composition and of physicial structure.

Circulars have been issued by the committees of the Board requesting men of science, engineers and manufacturers of metals to communicate to the Board all information which they may be able to submit relative to the subjects under investigation. A considerable amount of valuable material has thus been obtained. Even foreign correspondents of the Board exhibit great interest in the matter, and some of the most useful papers received by the Secretary were sent in by Mr. Forrest, the Secretary of the British Institution of Civil Engineers, Mon. Tresca, of the French Conservatoire des Arts et Metiers and other well-known European authorities.

A chemical laboratory has been established at Watertown Arsenal and the chemist to the Board, Mr. Andrew A. Blair, formerly of St. Louis, has already done a large amount of work upon irons, steels and other metals and alloys, and the specimens thus examined as to oomposition are subjected to the several kinds of mechanical stress to discover the effect of composition in determining resistances for distortion and rupture.

A series of steels is in preparation under the direction of the Committee on Chemical Research, in which other elements being retained constant in amount, the carbon varies regularly from 0 to 2 per cent.; another series, with carbon uniform, has silicon in varying proportions ; another set varies in phosphorus, still another in sulphur, and another series is variable in manganese. In each series, one element varies between wide limits, while the other elements are all retained as uniform as possible. The work of the melter is checked by analysis, and the specimens are then tested mechanically. This investigation, greatly as it has been needed, has never before been even attempted. It is considered by the members of the Board as likely to prove the most valuable research ever made in this direction, and the only one in which the chemist and the engineer have ever systematically joined forces in making such an exhaustive and scientific investigation.

The Committee on Abrasion and Wear is engaged in collating information relating to this subject, and is making experiments at the Stevens Institute of Technology on the abrasion and wear of the metals, and on the effect of lubrication in reducing it. The Chairman is fitting up machinery and apparatus for use in further investigation. A considerable amount of work has been done.

The Committee on Armor Plate is engaged in collating information from domestic and foreign sources that may be valuable in determining the qualities requisite in armor plate, and how those qualities are to be secured. The records of the Army and Navy Departments and of the British Admiralty are considered to be the most promising mines of information to be worked by this committee.

The Committee on Chemical Research has charge of the chemical work referred to.

The Committee on Chains and Wire Rope is endeavoring to determine the character of metal best adapted to making chain and rope, and the proper form and proportions of link, and is working up the data which have long been collecting at the Navy Departments. The later experiments of Com. Beardslee are extensive in range, and that officer is collating and arranging the records for the use of the Board. Further experiment will fill up any hiatus that may be detected. The Navy Yard at Washington, where this work is going on, affords peculiar facilities not only for testing, but for making chain cable of any desired size, form of link or quality of metal.

Work already done there by the Chairman of this committee has revealed serious defects in accepted tables of sizes and strength, and has indicated the rate of variation of strength with variation of size of bar, and permitted the formation of a new and trustworthy table.

The Committee on the Corrosion of Metals is investigating the conditions affecting the corrosion of metals in use. Some information has been collected, some chemical work has been done, and much more work is projected for the ensuing year.

The Committee on the Effects of Temperature has planned an extended investigation of this subject and is gathering information from various sources. The research will be commenced by the Chairman during the coming year, if the Board is sustained in its work. The Chairman has already collated all published information accessible in periodical literature, has made some preliminary experiments, and is receiving some information from various directions.

The Committee on Girders and Columns has a plan of operations which includes elaborate investigations of the strength of materials in columns and girders of various forms and proportions. This is the most formidable and expensive of the researches to be undertaken by the Board, and the power and accuracy of the 400 tons testing machine will be fully taxed in this work. The committee is receiving the co-operation and active aid of some of the largest manufacturers of beams and girders in the country. The results of experiments already made have been communicated to the committee by the engineers of railroads and of mills, and in other cases important and costly experiments have been undertaken by private incorporated companies (the Board has been invited to be present and to assist in the work if it should seem desirable); these results are to be given the Board, such sizes and proportions as the Board may desire to test are to be made and all necessary labor furnished without any expense to the government. Bridge builders, civil and mechanical engineers and architects are corresponding with the Board on this subject, and the greatest interest and a most gratifying public spirit are said by the members to be exhibited on all sides.

The Committee on Malleable Iron has collated a large mass of valuable information, and the records of a great number of experiments, and, among other important matter, has obtained an extensive collection of experimental determinations of the effect of time upon the elevation of the elastic limit by strain, during periods varying from a few seconds up to a year. The variation of quality due to differences of size and form of section of the bar and the modification of strength, ductility and resilience are under investigation. The Chairman of this committee is also determining the influence of proportions of test-pieces upon their ultimate resistances.

The Committee on Cast Iron is pursuing a course similar to that of the Committee on Malleable Iron with similarly promising results.

The Committee on Metallic Alloys has made an investigation of the strength and other properties of bronzes, which may be taken as typical of the kind of work to be done by the Board.

Several series of copper-tin alloys were prepared, varying in some cases by regular percentages, and in others by chemical equivalents, and were cast in bars of 1 inch square section and about 20 inches long. Their temperatures of fusion were taken at casting, and some were cast in sand, and others in an iron ingot mould. The weighing was carefully done in a Coast Survey balance, in the Physical Laboratory of the Stevens Institute of Technology. A set was reserved for the determination of the coefficient of expansion, by Dr. Mayer. The others were broken by transverse stress, one set by dead loads, and others in the transverse testing machine of the Mechanical Laboratory, and deflections and tests were recorded to the fourth place of decimals, in inches, and also in meters with equal precision. The logs were made up, and the results were also laid off graphically. The curves revealed some peculiar and important facts. The fractures were photographed and, were peculiar, were reported upon by Prof. Leeds, the chemist and mineralogist of the Institute. From the data obtained, the co-efficients of elasticity were calculated and recorded

Complete sets were next broken by tension, and the results recorded and worked up as with the transverse tests, and the logs and curves compared, and a series of compression specimens were made up as companion test-pieces.

The full series was finally tested in the autographic recording machine and from the strain diagrams, their strength, elasticity, ductility, resilience and homogeneousness were deduced, and the law of variation worked up graphically. The effect of strain in elevating the elastic limit was observed.

All specimens were examined by the chemist, and a comparison made between the proportions by mixture and composition in the bar which exhibit the loss of metal, and to some extent, change of physical character, produced by melting and casting. Some curious and interesting scientific facts are revealed by the research, and a new mineral consisting of stannic acid, with a trace of copper in magnificent needle-shaped crystals was produced in some cases, which has been subjected to examination and analysis by Prof. Leeds.

A determination of specific gravities of the metals as purchased, as cast and as compressed mechanically and in mass and in a state of fine division, concludes this research.

A similar research is in progress, under the direction of this committee, by Prof. Thurston, its Chairman, which is intended, also, to be as complete and accurate as the resources at command will permit.

Before entering upon this work, the Chairman collated all published material bearing on the subject, and a preliminary report of about one hundred pages embodies the most important facts previously determined, and contains the bibliography of this subject of copper-tin alloys. This work was supplemented by making graphical records of the experimental work of Mallet, Mathiessen, Calvert, Johnson and others on the conductivity for heat and electricity, the specific gravity and other properties of copper-tin alloys, as had been examined by them. It was the intention to profit by facts already acquired by acknowledged authorities, to complement them by the new investigations, and to avoid useless repetition of work involving serious expenditure of time.

This paper is itself regarded as exceedingly valuable, and particularly to the mechanical

engineer, as it is the first time that these earlier researches have ever been collected and put in an accessible and compact form.

A similar preliminary research is made to preface the examination of the copper-zinc alloys, and the same plan will be pursued throughout.

The Committee on Orthogonal Strains is planning a series of experiments to determine the laws of the resistance of materials under simultaneous stresses acting in rectangular directions, as in the case of a rod subjected to torsional or shearing simultaneously with tensile or compressive stress. The subject has been entirely unstudied up to the present time.

The Committee on Physical Phenomena is preparing to seek for the phenomena induced by stress in the various physical models of energy, as the development of magnetic, electric and thermal actions. The fact of the development of heat and electricity has long been known, but no systematic or scientific investigation has ever been made in this direction.

The Committee on Steel produced by Modern Processes is working with the Committee on Chemical Research. It is collecting also the vast mass of material available and will endeavor to make a report which shall be of great and permanent value.

The Committee on Re-heating and Re-rolling is to test iron &c., in the several stages of manufacture, refined and unrefined, and to observe the effects of successive re-heats, of re-working and rolling, to determine, if possible, what amount of work is demanded by different irons, and what are the temperatures which will practically give the best results.

The Committee on Steel for Tools is making an extended series of experiments at the Washington Navy Yard to determine the value of various steels for tools. A large collection of steels is made ; their composition is determined, and they are there carefully tested by setting them at work—turning, planing, boring and chiseling—and their behavior and their composition being thus ascertained it will probably be easy to learn the chemical and physical characteristics of the best tools. The names of makers are of no importance in this investigation, and are not to be reported. The Board, in all its work, will avoid reference to makers of material in any way that may injure any manufacturer directly or indirectly. Scientific knowledge of directly practical value and engineering facts and figures, solely are sought.

The testing machine ordered by the Board is well under way, and it is expected will be soon completed, when the Board will be prepared to undertake the heavier and more accurate work laid out by its committees. The machine was designed by Albert H. Emery, and has an attachment designed by Charles E. Emery, for obtaining an autographic strain diagram. Its capacity is 800,000 pounds, in both tension and compression. The committee of the Board appointed to examine and report upon it, considered it an extremely accurate and effective form of machine, and far superior to any other then known to its members.

The building, the foundation, and the accessory machinery are all in hands, under the charge of the several committees of the Board entrusted with these matters, and will be ready for the machine before its completion.

The Board is not prepared to make a report, as all the work is in progress and none yet completed. If desired, the members state their willingness to present to the appointing power, and to Congress, a statement of their status. They expect to be able economically, to use $50,000 during the year 1876–7.

At a meeting of the Board of Direction of this Society, held February 9th, 1876, the plans and work of the Board were considered and the followiing adopted :

Whereas ; the Board of Direction, of the American Society of Civil Engineers has informed itself as to the work performed, in hand, and proposed by the United States Board appointed to test Iron, Steel and other Metals, and has been led by such information to the following conclusions :

1st. That the 400-tons testing machine ordered by the Board and now nearly three-fourths completed, has been built under extraordinary close inspection, and is remarkably well built, both as to material and workmanship.

2d. That even without the use of this testing machine, the Board has accomplished a large amount of useful work, viz.:—The establishment of a chemical laboratory and the engagement of an experienced chemist ; the arrangement of a comprehensive series of comparative chemical and physical tests and the already completed analyses and preparation of specimens for test from a large number of irons and steels containing different hardening and toughening ingredients ; also the preparation of a complete series of specimens of the various bronzes, a number of which has been submitted to analysis and to a part of the necessary mechanical tests—the results of which must be that all these materials can be more closely adapted to the large variety of stresses they will have to bear in use, thus avoiding the present excess of material and cheapening structures and machinery as well as increasing their safety, and also making the production of materials a matter of scientific synthesis rather than a trade secret ; that the board has collected and classified a mass of information about the useful work done elsewhere in testing metals ; that it has commenced a comprehensive series of experiments on tool-steels and arranged for the construction of some large iron and steel columns and girders for tests ; that it has availed itself of the results of a series of tests of wrought iron, especially in the form of chain cables, previously undertaken by one of its members for the Navy department, and has commenced more comprehensively carrying out these experiments and completing their usefulness by means of chemical analysis ; and that it has prepared as far as its means will allow, to undertake tests in other departments.

3d. That the character of the experiments undertaken and proposed by the Board is judicious and comprehensive, and if carried out

on these plans, will be of great value to engineers, constructors, producers of constructive materials and the public at large.

4th That the information derived from these experiments should be of the first and greatest value to the Government directly, in its own constructions of vessels, engines, boilers, cannon, armor plates, light-houses, etc.

5th. That in order to carry out to comprehensively useful results, the series of tests already undertaken, the Board will require a considerable sum of money, chiefly to increase its chemical department and to pay for material to be tested, and for the manufacture of such new shapes and compounds as current tests may prove it desirable to experiment upon.

Therefore it is Resolved—That the Board of Direction of the American Society of Civil Engineers respectfully petitions the honorable Senate and House of Representatives in Congress assembled, to grant to the United States Board appointed to test iron, steel and other metals, the sum of fifty thousand dollars, to be expended in carrying out the investigations of the Board, as explained in its various printed circulars.

IRON AND STEEL NOTES.

The Iron Industry.—The American Iron and Steel Association has just published a directory of furnaces, rolling mills, steel works, forges and bloomeries in every State of the Union. The following is the summary of the number and capacity of the furnace and rolling mills in the United States :

	Tons of 2240 lbs.
Whole number of completed blast furnaces January 1, 1876.....	713
Annual capacity of all the furnaces..........................	4,856,810 tons.
Whole number of rolling mills, January 1, 1876.......... ...	332
Whole number of single puddling furnaces (each double furnace counting as two single ones)......................	4,475
Total annual capacity of all rolling mills in finished iron.....	3,740,860 tons.
Annual capacity of all the rail mills in heavy rails..........	1,732,410 tons.
Number of Bessemer steel works January 1, 1876..............	11
Annual capacity in ingots.. ..	450,000 tons.
Number of Bessemer converters	24
Number of open hearth steel works January 1, 1876.......	16
Number of open hearth furnaces	22
Annual capacity in ingots......	41,000 tons.
Number of crucible and other steel works January 1, 1876..	39
Annual capacity of merchantable steel.....	97,550 tons.
Of which there are of crucible steel.......................	41,000 tons.
Number of catalan forges making blooms direct from the ores January 1, 1876.........	39
Annual capacity of blooms and billets.......................	53,080 tons.
Number of bloomeries January 1, 1876, making blooms from pig iron	59
Annual capacity in blooms....	53,750 tons.

French Treatment of Slag.—A new French process for the treatment of slag is claimed to realize the most profitable results yet obtained in the utilization of that hitherto worthless material, notwithstanding the various successful efforts, which, within a comparatively recent period, have been put forth in this direction.

The method in question, as described, is not to employ the slag directly, to form artificial stone or pressed bricks, but to reduce it to a fine state of division, in which it becomes capable of a great variety of uses in addition to those for which it was originally supposed to be adapted.

The channel through which the molten slag flows from the furnace is made, in this arrangement, to terminate in a running stream of water leading into a pit or excavation. On striking the water, the lava stream of slag is blown and broken into a sort of fine, porous gravel, which the flow of the water then bears along into the pit. Meanwhile, the iron grains contained in the slag, which previously were separated by crushing, are now sorted out by this water process, sinking to the bottom by their weight, instead of being carried on with the rest. The slag sand accumulating in the pit is charged thence into wagons or railway cars by means of an endless chain and buckets driven by an engine run by hot gases from the furnace.

Thus treated, the artificial sand or granulated slag is said to be not merely easier and cheaper to get rid of, but applicable to a number of valuable uses. One of these is for casting sand, pigs made in such a bed coming out exceedingly handsome and bright. For this purpose the material is now very largely used in some parts of France, Belgium and Prussia. The next step was a natural outgrowth of the last, namely, to use the finer portions, separated by sifting, to sand the moulds for fine castings ; thus employed it is found cleaner and better than common sand, and the castings are improved. Another use to which this artificial or metallic gravel is put is that for ballasting railroad tracks, for which it is very serviceable.

Being also very porous, packing well, and holding but little wet, this slag sand forms a valuable concrete like mortar, and not only this, but is capable of being used for cement. This is regarded, in fact, as its most important specialty, it being found that first-class cement can be thus obtained from almost any slag at a very small cost ; a large manufactory having been erected for this purpose, after long and full experiment at one of the leading German works.—*Iron Age.*

RAILWAY NOTES.

Creeping of Rails.—The "creeping" of railroad rails has attracted some attention of late, and, while we do not attempt to explain

it, we offer a point on the fact that on lines running north and south the western rail "creeps" faster than the eastern rail,—that is, this strange movement of the rail toward the south is more marked in one rail than in the other on the same track. Furthermore, it has been noticed that on such a line the eastern rails wear out the faster. Both of these points, we think, can be explained by the motion of the earth as it turns from the west towards the east. Everything that has free motion is dragged after the whirling globe; every wind that blows and every tide that moves feels the influence, and our train going north or south is pulled over toward the east, and naturally presses the eastern rail most heavily. The western rail, being relieved of its share of weight, "creeps" more freely and quickly. It is also noticed that the wheels that run on the eastern rail wear out the first, and we can but think that this earth motion is the true cause. The practical side of this is that the eastern wheel and rails should be stronger.

STEEL GRADIENT LOCOMOTIVES.—The New Zealand railways being, as is pretty well well known, laid over hills with some rather severe inclines, have to be worked on a somewhat similar system to that employed on the Mont Cenis railway. The gauge is 3 feet 6 inches, and there is a central rail at an elevation of 6½ inches above the level of the two outer ones constituting Mr. Fell's system. The Government has ordered four locomotives of an improved type, which are now being made from their own designs by The Avonside Engine Company (Limited), of Bristol. So much thought has been expended on these engines, and so many special contrivances introduced, producing in the end so splendid a result, that Mr. John C. Wilson, the engineering and general manager of the Avonside Company, has every reason to congratulate himself on his work. On Saturday last one of the locomotives was tried on a short temporary line of railway, laid down in the yard of the Bristol Wagon Works, by the kind permission of Mr. Fry, the managing director. Here tests of every imaginable description were applied, and the results were uniformly satisfactory. The line was too short, however, to make any experiments such as those tried by the Railway Accident Commission, at Newark, much to the regret of the spectators, as the special brake answered so admirably that it would have been interesting to learn exactly how short the distance really was in which the engine was stopped against full steam.

The length over all of the locomotive is 21 feet 6 inches, and its width 9 feet 3 inches. It is driven by two pairs of wheels, coupled, of 2 feet 8 inches diameter, on which about 28 tons of the weight rest, and the trailing wheels are 2 feet 6 inches diameter, carrying about 6 tons, the total weight of the engine being about 34 tons. The trailing wheels are fitted with the "radial axle boxes," patented by Mr. H. W. Widmark, of Bristol. These are intended to provide for the easy turning of curves, and are adapted in this instance to curves of the short radius of 300 feet. They are provided with cylindrical guides, and with planes set at an angle to the central line of the axle, while at the top are inclined planes calculated to give much elasticity. We understand that these axle boxes have given good results in working, and on Saturday it was evident that a considerable amount of play was given as the engine rounded the curves of the experimental line. The boiler is arranged for a variation in water level corresponding to an inclination of 1 foot in 15, this being the steepest slope on the New Zealand lines. It has 170 tubes of 1¾ inches diameter and pitch of 2 $\frac{7}{16}$ inches. The grate area is 13 square feet, and the heating surface of the fire-box 74 square feet, that of the tubes being 783 square feet, affording a total of 857 square feet. The tanks hold 614 gallons, and the coal-box has a capacity of 36 cubic feet. The driving engine for the vertical or ordinary wheels consists of a couple of cylinders of 14-inch diameter and 16-inch stroke, while a smaller pair of cylinders of 12-inch diameter and 14-inch stroke work the four horizontal wheels of 22½-inch diameter which grip the central rail. These may be called the outer and inner engines respectively, and the gearing is so arranged that either may be worked separately, or they may be worked simultaneously, either in harmony or antagonism. Two pairs of volute springs keep the horizontal wheels apart, while a couple of powerful crescent spring exert a pressure of 28 tons to bring them together. This is, of course, the useful pressure upon the centre rail, while a corresponding amount is exerted upon the driving wheels, thus giving the large quantity of 56 tons useful adhesion for a 34-ton locomotive. The valve motion for the inside (Fell) engine is an adaptation of Walschart's system. The brakes are double—the ordinary lever-brake being fitted to the driving wheels, whilst a highly efficient brake is fitted to the central rail, gripping it like a pair of nutcrackers. Another noteworthy minor feature is a peculiar link motion in the coupling, which is Stradal's and is so arranged that even with the utmost lateral motion a pull away takes effect on the central line of the vehicle.

These locomotives are intended to work in pairs, being coupled end to end, so that the drivers work together, with one stoker between them, and they are calculated to draw 100 tons up an incline of 1 in 15 at a rate of five miles an hour. The following are the principal results of Saturday's trial.

(1) Either engine alone was sufficient to drive the locomotive, and a *fortiori* both together drove her admirably.

(2) The engines being set to work against each other, *i. e.*, the outer ones being driven forward and the inner ones reversed—the latter, gripping the central rail, proved to be more powerful.

(3) Both engines being at work, the brake power was sufficient to stop the locomotive—steam being full on at 125 lb.—within three or four times her own length.

ENGINEERING STRUCTURES.

THE IMPROVEMENT OF THE DANUBE.—At a meeting of the Edinburgh Royal Society,

held lately, Sir Wm. Thomson presiding, Professor George Forbes read a paper, principally founded on theory and intended to show a connection between cohesion, elasticity, dilatation and temperatare. Mr. Stevenson followed with a notice of the completion of works designed by Sir Charles Hartley, for improving the Danube. He reminded the meeting that in 1854 a commission of eight delegates, representing the different powers in Europe, was appointed to adopt means to improve the Danube, so as to make it accessible to the shipping of all nations. The Danube entered the Black Sea by three mouths, and it involved a good deal of discussion as to which of these should be chosen as most suitable for their operations. Soulina, as the mouth discharging the least water, was not apparently the one which would have been selected, but the particular circumstances of the Danube led them ultimately to this decision. The discharge of alluvial matter from the three mouths was most enormous, amounting to 900,000 tons every twenty-four hours. Soulina discharged only 70 000 tons, but even this deposit embraced a very difficult engineering problem. In dealing with it Sir Charles Hartley advised the commission, and the advice was followed, to construct piers on both sides, so that the water might be narrowed and the deposit carried into the deep water of the Black Sea. The works had been executed, and the practical result of it had been that, while in 1854 the natural depth at the Soulina mouth was 11 ft., the depth of 20 ft. was now maintained. The piers were 8,000 feet in length, and had cost £180,000. As regarded navigating, there had been an increase of shipping of 16 per cent. on the number of vessels, and an increase of tonnage of 50 per cent The number of shipwrecks had also been greatly diminished.

A Proposed Bridge Across the Thames.—Lately Mr. Frederic Barnett laid before the Society of Arts a proposition for a new bridge; for providing for the traffic across the Thames below London Bridge. Mr. Barnett said: "My patent bridge has but one approach from each shore. When these approaches have extended into the river about one-third its width, the roadway splits into two roads, each the same width as the approaches, by easy inclined angles, outwardly extending till they meet midway, thus forming a sort of angular oval or loop in the largest diameter. I have on each side two openings, practically covered and united by platforms, turning on their centres, each opening or closing by one operation. These openings permit the entrance on the port side of the largest ships that come up the Thames; there is also a sufficient width allowed for the length for the ships within the loop. From the central piers on which the turntables work, there is extended a platform uniting the two extremes, so that this platform lies with the axis of the river, dividing the loop into halves, furnishing the means of mooring the ship a few minutes alongside by mooring blocks. There are two other platforms running parallel to the chief platform, which keep the ships straight on their road. The vessels return on the opposite, still going port; thus all risk or collision is avoided. The platform will have narrow lighters, rising and falling with the tide, thus protecting both piers and vessels from injury. As soon as a vessel is about to enter the loop, the roadway on the side by which it is to enter is closed, and the vehicular and general traffic, by closing the gates (when the roads divide), is diverted to the opposite side; then immediately the turntable-bridge is opened, and the vessel enters the loop, so that when it is fairly in, the bridge is closed behind it, and, as before described, the traffic is diverted on the road behind the ship, and the opposite turntable-bridge is opened, suffering the ship to pass out on its way."

Such a structure as that proposed would block up the river and prove an enormous nuisance. Further consideration of it would seem to be useless.

ORDNANCE AND NAVAL.

Facts About the Big Guns.—The following statement of the costs and sizes of the "big guns" of Europe will be found of interest: The 81 ton gun has cost $75,000, and the price named for the "Newcastle infants," of 100 tons for the Italian navy is, $120,000 each. We have not seen it stated what the Krupp monster is to cost, but it will probably be $150,000 or more. The testing of these guns, to say nothing of their use in actual service, adds not a little to this enormous expenditure. Every time the 81-ton piece is fired it blows $125 into the air, 240 pounds of powder and a projectile of 1260 pounds being the charge in the first trials. In some of these rounds, 250 pounds of powder and a 1465 pound shot were used. It is now proposed to increase the bore of the gun from 15½ inches to 16 inches, after which operation the charge will be proportionately augmented. The Italian guns are to fire projectiles of 1860 pounds each, while the Krupp cannon will send a ball of 1040 kilogrammes, or about 2300 pounds, through the air; how much powder is to be used in doing it we are unable to say. One gets, however, a new idea of the power of gunpowder when he learns that a few hundred pounds of it can propel a missile of more than a ton's weight over a distance of several miles. In the case of the 81-ton guns the shot of 1260 pounds left the muzzle with a velocity of 1400 feet a second, and a momentum that would carry it through 20 inches of iron plating at a range of half a mile. The Duilius, for whose armament the four 100 ton Armstrong guns are intended, is described as being the most powerful iron plated frigate ever yet devised. She is to be armored with plates 19 inches in thickness, and moved by engines of 7000 horse-power.—*Engineer.*

BOOK NOTICES.

A Practical Treatise on Roads, Streets and Pavements. By Maj.-Gen. Q. A. Gillmore, A. M. New York: D. Van Nostrand. Price $2.00.

We gave considerable space last month to a

review of this work, containing some important extracts. The entire scope of the work will be better understood by the following extract from the table of contents :

Chapter 1. Location and Grades of Country Roads ; 2. Earthwork, Drainage and Transverse Form of Country Roads ; 3. Road Coverings ; 4. Maintenance and Repairs of Roads; 5. Streets and Street Pavements ; 6. Sidewalks and Footpaths ; and 7. Tramways and Street Railways.

Illustrations accompany every chapter.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION. Nos. 80, 81, 82. London. For sale by D. Van Nostrand.

Every issue of this valuable journal contains something nearly indispensable to the engineering profession. In the above numbers we find Comparative Merits of Simple and Compound Engines ; The New Works for the Defence of Paris ; The Unsurveyed World; Harbor Defence ; Signaling by Explosions ; The Macomber Gun; Military and Refuge Harbors.

Maps and other illustrations are abundant.

MATHEMATICAL TABLES. New Edition. London and Edinburgh : W. & R. Chambers. For sale by D. Van Nostrand. Price $1.75.

This is a well printed volume of convenient size, containing, besides the common mathematical tables, a useful compend of the various nautical tables, together with tables for conversion of thermometric scales and for binomial co-efficients used in interpolation.

HYDRAULIC EXPERIMENTS AT ROORKEE. By Capt. ALLAN CUNNINGHAM, R. E. Roorkee : Thomason College Press.

This book is an extra number of the series of "Professional Papers on Indian Engineering."

The experiments referred to were performed in the Ganges Canal in the neighborhood of Roorkee. The conditions were unusually favorable for a comparison of methods : The canal here presents within a reach of six miles three sorts of channel ; 1st, A Trapezoidal Channel in Earth, three miles long, and 150 feet average width ; 2d, A Trapezoidal Channel in masonry, two miles long and 150 feet wide ; 3d, Rectangular Twin Channels, 932 feet long, and each 85 feet wide; then a fourth section of half a mile length follows of the same description as No. 2.

The different methods known to engineers for measuring the velocities, and deducing therefrom the actual discharge of streams, were evidently tried with scrupulous care, and the results are carefully recorded in the book before us.

The value to the practical engineer of such a record of experiments is not easily over estimated. In this branch of engineering particularly are we in need of carefully prepared data to enable us to reconcile conflicting professional opinions, or else to aid us in choosing between them.

We have no space here for such extracts as would do justice to the writer. In our next issue, however, we will give at least a summary of the results obtained.

GUIDE POUR L'ANALYSE DE L'EAU. Par Dr. E. REICHARDT. Paris : Reinwald et Cie. For sale by D. Van Nostrand. Price $1.80.

A pamphlet only of 100 pages, but treating the subject systematically and thoroughly.

The chemical processes are fully described both for qualitative and quantitative examinations. The microscopic analysis receives a fair share of attention, and is illustrated with excellent woodcuts of the crystaline deposits.

A MANUAL OF QUALITATIVE CHEMICAL ANALYSIS. By WM. DITTMAR. Edinburgh: Edmondston & Douglas. For sale by D. Van Nostrand. Price $2.50.

This is a well printed and well arranged book for students. There is no pretension on the part of the author that anything particularly new is presented in the way of methods or classification, which is much in its favor. The book, however, is certainly up with the times, and more than the usual amount of space is devoted to the rationale of processes.

A GUIDE TO THE MICROSCOPICAL EXAMINATION OF DRINKING WATER. By J. D. MACDONALD, M. D., F. R. S. London : J. & A. Churchill. For sale by D. Van Nostrand. Price $3.50.

The text of this work is very brief, and is but little else than a zoological table of classification, but there are twenty-four full page plates of representations of living things as they appear under the microscope.

If it is proven that these are the regular inhabitants of ordinary drinking water, the temperance reformers will not find an ally in this author.

AN ELEMENARY TREATISE ON KINEMATICS AND KINETICS. By E. J. GROSS, M. A. London, Oxford and Cambridge : Rivingtons. For sale by D. Van Nostrand. Price $2.75.

This a brief treatise on elementary mechanics, with numerous examples for practice. It is designed for students who are not proficient in Analytical Geometry or the Calculus.

For students who are reviewing and preparing for college examinations, the work will prove of great convenience by reason of the abundance of examples requiring application of important principles. A key to all the solutions is given in the appendix.

EXERCISES IN ELECTRICAL AND MAGNETIC MEASUREMENT. By R. E. DAY, M. A. London : Longmans, Green & Co. For sale by D. Van Nostrand. Price $1.25.

Nothing in the way of preparatory explanation is afforded in this book. It is a collection of examples for the student with answers in the appendix.

No better way could be devised for attaining familiarity with the practical applications of electrical science than practising upon these examples. But it is necessary to warn the student that he is not prepared for the work when he has simply accomplished the course in science which is at present prescribed in the schools. Some familiarity with the science of the telegrapher and the physicist as set forth in later practical treatises is necessary for a beginning with these useful exercises.

Physical Geography or the Terraqueous Globe and its Phenomena. By Wm. Desborough Cooley. London: Derlau & Co. For sale by Van Nostrand. Price $10.50.

An octavo volume illustrated with 125 wood engravings and 12 maps.

All the topics usually presented under this comprehensive title are presented in logical order, and with proper regard to space due to each subject. In such a cursory glance as we were enabled to give the work, we noted a gratifying absence of statistical tables, which lend to some of the late works on Physical Geography an uninviting look to say the least. We, moreover, found it impossible to turn away from the book without reading thoroughly all the author presented on the subject of Tidal Phenomena and on Glaciers and the Theories of the Glacial Epoch.

We can therefore heartily recommend so much as valuable, and we presume the entire treatise is also.

Lectures on Some Recent Advances in Physical Science. By P. G. Tait, M.A. London: Macmillan & Co. For sale by Van Nostrand. Price $2.50.

Nothing is more acceptable to the lover of science and scientific literature than an occasional summary of scientific discoveries, provided always that such a summary is prepared by competent hands. Such is the present book by Prof. Tait.

The lectures bear the following titles: 1, Introductory; 2, Early History of Energy; 3, Establishment of the Conservation of Energy; 4, Transformation of Energy; 5, Transformation of Heat into Work; 6, Transformation of Energy; 7, Sources and Transference of Energy; 8, Radiation and Absorption; 9, Spectrum Analysis; 10, Spectrum Analysis; 11, Conduction of Heat; 12 and 13, Structure of Matter.

The typography is good, and the few illustrations are of fair quality.

Annual Report of the Chief Signal Officer to the Secretary of War for the Year 1875. Washington: Government Printing Office.

Whoever takes pride in the establishment of the Signal Bureau of the United States should become possesssor of the voluminous report for 1875. He can then justify his patriotic feeling by ready reference to the printed record.

We rejoice in the fact that the Bureau has become so firmly established, that its continuance is no more a question than that of the ready distribution of the mails. The management has been from the first in the most thoroughly competent hands. Only a few years since such a department was not in existence, and its uses were not dreamed of by the general public; now we have the most efficient system of observation and report known to the world, and the advantages are warmly acknowledged by all who read the daily papers. We doubt not the public voice would favor any extension of the system that its director deems desirable; it would thereby do justice to an efficient public officer.

Traite Pratique du Chauffage par le Gaz. Par Gustave Germinet. Paris: Eugéne Lacroix. For sale by Van Nostrand. Price $1.00.

This contains brief but lucid descriptions of the various pieces of mechanism employed when the combustion of gas is made to play an important part in many industrial operations.

Besides the little heaters for warming or cooking, which are well known here, several modifications of the compound blow pipe are described, which are used for soldering, brazing and other common operations of the mechanics' shops.

Light as a Motive Power: A Series of Hydrographical Essays. By Lieut. R. H. Armit, R. N. 2 vols. 8vo. London: Trubner & Co. For sale by D. Van Nostrand. Price $15.00.

In glancing over the second volume of these essays (the first has been published some time) we are constrained to sympathize with the reviewer of the first volume who declined to follow where the author would lead.

In the few places where the author, by the proper use of scientific terms, has expressed an opinion upon oceanic or atmospheric circulation, we have no hesitation in rejecting his conclusions. But we confess to have felt a certain degree of interest in the more numerous passages where acknowledged facts and familiar terms are misused—that kind of interest which one feels in mild forms of conundrum. But this interest is not sustained for the reason that there is no known solution of the conundrums.

We offer a few samples from the second volume. If the reader enjoys them he will be satisfied to know there is plenty of them in the same book.

The author begins to "sum up" on page 213 in the following terms:

"And we hold that we have established the *unity* of the following points:

"1. That electricity is that fluid which, under different names, be it galvanism, magnetism, electro-galvanism, or electro-magnetism, binds the whole universe together and exerts that force which science calls gravity.

"2. That electricity is *Light*, *Heat* and *Cold*, and is therefore one body divided into three substances, and that all these are *Motive Forces*.

"3. That heat, light and cold are *Life*.

"4. That some obscure process of evaporation is continually going on throughout the mineral formation of the globe—we might say of the universe," etc., etc.

It makes but little difference where we stop, as the object is merely to offer a fair sample of the book.

MISCELLANEOUS.

It is stated in a Vienna telegram that in order to obtain the means for providing new artillery for the army a loan is in contemplation, contracted jointly by both halves of the empire. By this course it would be possible thoroughly to re-equip the artillery regiments at once, and to distribute the cost over a lengthened period.

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ECLECTIC
ENGINEERING MAGAZINE.

NO. XC.—JUNE, 1876.—VOL. XIV.

CALCULATIONS OF STRAINS IN ARCH BRIDGES.*

By CHARLES PFEIFER, C. E.

RESISTANCES OF ABUTMENTS AND DEFLECTIONS OF ARCH PRODUCED BY MOVABLE LOADS.†

LET A C A_1, Fig. 1, be the centre line of a rib of an upright arch bridge; O its center; A A_1 the span of the center line, C D the versed sine. Let the movable load be supposed to extend from A to any point B, and to be equally distributed horizontally. Let F be any point of the center line. Let A be the origin of rectangular coordinates, A A_1 being the axis of x, and put

x, y=the coordinates of F before flexure,

x_1, y_1=the coordinates of F after flexure,

δ=C O F,

β=C O B,

α=C O A,

R=the radius of the center line,

$2\,a$=the span A A_1,

h=C D,

$n\,a$=the horizontal distance of B from A,

q=the load on a rib per unit of length (measured horizontally),

then, putting also $x=m\,a$, we have the relations

$$1\left\{\begin{aligned} x=m\,a&=\text{R (sine } \alpha-\text{sine } \delta),\\ y&=\text{R (cos. } \delta-\text{cos. } \alpha),\\ n\,a&=\text{R (sine } \alpha-\text{sine } \beta),\end{aligned}\right.$$

whence, since a=R sine α, we have for computing the values of δ and β for any given values of m and n,

$$2\left\{\begin{aligned}\text{sine } \delta &= (1-m) \text{ sine } \alpha,\\ \text{sine } \beta &= (1-n) \text{ sine } \alpha,\end{aligned}\right.$$

The reactions caused by the load $q\,n\,a$ at the abutments A and A_1 may be represented by their resultants, single forces T and T_1, intersecting the radial planes through the ends of the arch at the points G and H, whose distances from A and A_1, measured towards the center O, are b and b_1. If the points G or H should be above A or A_1, b or b_1 would be negative.

The forces T and T_1 may be replaced by their vertical and horizontal components P, Q and P_1, Q_1.

As the forces acting on the arch must be in equilibrium, we have the following equations:

* A paper prepared for the Engineers' Club of St. Louis, Mo.

† A great part of the contents of this paper has already been published in the appendix to the report of the Chief Engineer of the Illinois and St. Louis Bridge of 1868, containing the calculations for this bridge. The arrangement of these calculations for publication was intrusted by the Chief Engineer, Capt. James B. Eads, to the late W. Chauvenet, LL. D., Chancellor of Washington University, formerly Professor of Mathematics in the U. S. Naval Academy at Annapolis. As I could not expect to improve on his arrangement, I took the liberty of copying from it whatever I could use, considering the wider scope of this present paper.

3. $P_1 = -P + qna$ (sum of vertical forces $= 0$),

4. $Q_1 = Q$ (sum of horizontal forces $= 0$),

5. $b_1 (P_1 \text{ sine } \alpha + Q_1 \cos. \alpha) = b (P \text{ sine } \alpha + Q \cos. \alpha) - 2 Pa + 2 q n a^2 \left(1 - \frac{n}{4}\right)$ (sum of moments around $A_1 = 0$).

The quantities $b(P \text{ sine } \alpha + Q \cos. \alpha)$ and $b_1 (P_1 \text{ sine } \alpha + Q_1 \cos. \alpha)$ are the bending moments at the abutments.

The equations 3, 4 and 5, which exhaust the conditions of *equilibrium* for the whole arch, determine the resistance of the abutment on the right side when those on the left side are known, but they give us no means to determine the latter. To obtain these we must consider the resistance which the abutments offer to the *deflection* of the arch.

This resistance depends

1st. Upon the construction of the abutments and the peculiar manner in which the ends of the arch are connected with them;

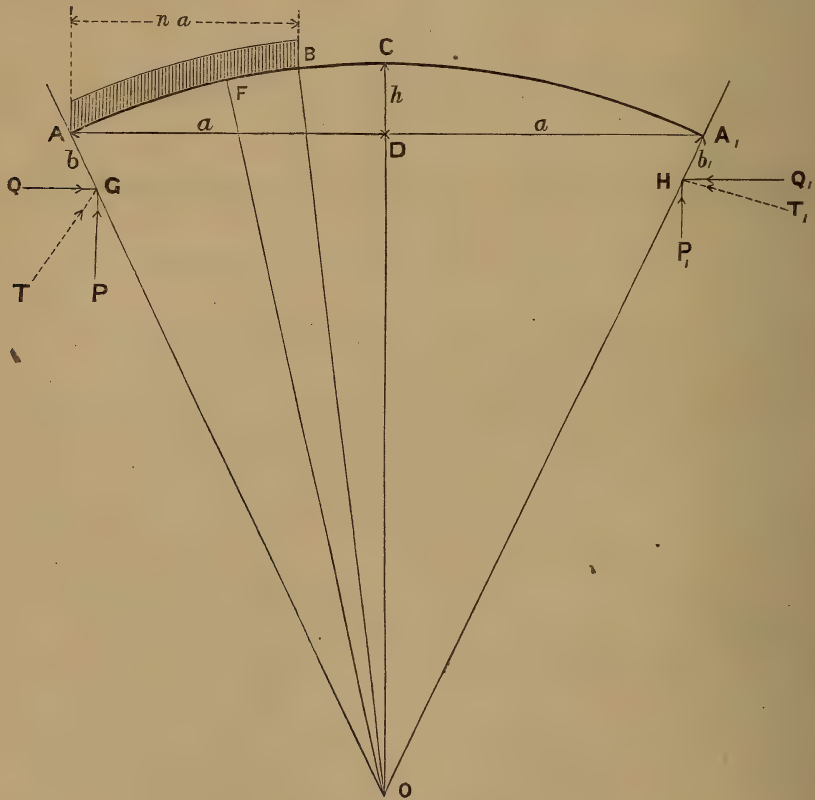

Fig. 1.

2d. Upon the properties of the arch itself, its form, cross-section, method of construction, etc.

For illustration, let us assume that the arch at A and A_1 end in pins, which rest on stools of which one is mounted on rollers as is done in truss bridges to avoid strains from expansion or contraction by changes of temperature.

It is evident that in this case the resultant of the resistance at each abutment must pass through the center of the end-pin, hence

$$b = b_1 = 0,$$

which makes also the bending moments at the abutments $= 0$.

On account of the rollers the abutments can offer no horizontal resistance, hence

$$Q = Q_1 = 0.$$

The vertical resistances of the abut-

ments may then be obtained by 5 and 3, viz.:

$$P=q\,n\,a\left(1-\frac{n}{4}\right),\text{ and }P_1=q\frac{n^2a}{4}$$

The arch is in this case but a girder with a high camber.

Let us now assume that the stools on which the end-pins A and A_1 of the arch rest, be firmly set into rigid abutments, but that the arch be constructed with a hinge in its crown at C, which prevents a bending moment at this point.

We have then again, as in the former case,

$$b=b_1=0,$$

$$P=q\,n\,a\left(1-\frac{n}{4}\right),$$

$$P_1=q\,\frac{n^2\,a}{4},$$

but we can no longer put the horizontal components, Q and Q_1, = 0, and have to determine them by the condition that the forces acting on the right half of the arch must have no tendency to turn it about the hinge at C. This condition is expressed by the equation

$$Q_1\,h-P_1\,a=0,$$

which, with the value of P_1 found above, and by equation 4 gives

$$Q=Q_1=q\frac{n^2\,a^2}{4\,h}.$$

In the cases just considered the determination of P, Q and b (P sine α + Q cos. α) from the peculiarities of the construction was very simple, but when there is no hinge in the center, or no pivots at the ends, it becomes necessary to consider the deflection of the arch in order to arrive at the proper values for the reactions of the abutments.

If A O B, Fig. 2, is the center-line of an elastic arch, any normal section of which, as H N, is a symmetrical figure

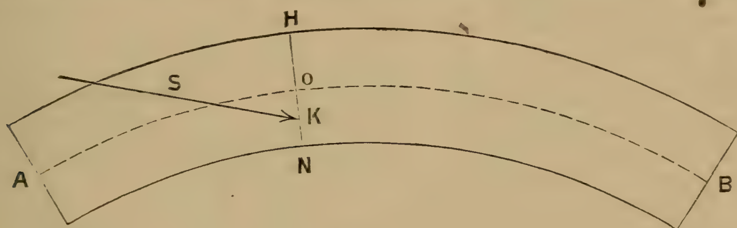

FIG. 2.

with respect to the center line, and if different external forces are acting in the plane of the center line, then the internal forces acting in the section H N on the portion A O of the arch have to be in equilibrium with all the external forces acting on the same portion. These external forces may be supposed to be first reduced to their resultant, a single force S acting at some point K in the normal plane.

The force S acting at K may then be

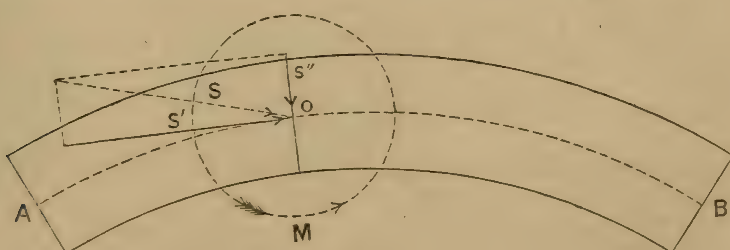

FIG. 3.

replaced by an equal force S (Fig. 3) acting at the center O of the normal section, and a couple of forces whose moment M tends to produce rotation about the point O.

Finally, the force S may be replaced by two components S′ and S″, one acting at O perpendicular to the normal plane, that is, in the direction of the arch at this point; the other acting in the nor-

mal plane, that is, in the direction of the normal to the arch at O. The force S′ produces a *compressive* or *tensile strain* in the direction of the arch; the force S″ the *shearing strain.*

The force S′, not exceeding the limit of elasticity of the material, a proper sectional area of the arch being furnished, has no tendency to change the curvature of the arch, and produce only a small variation in the length of the center line which at present we neglect.*

As we know further from experience that in an arch whose vertical thickness is small compared with its radius and with its length, and whose strains do not exceed the limits of elasticity, a plane section H N normal to the curve of the arch before flexure remains normal to the curve of the deflected arch, which could not be the case if the deflection was in any material degree influenced by the shearing strains S″, we may for all practical purposes consider the moment M as the sole agent in changing the curve of the arch.

Omitting therefore for the present the forces S′ and S″, we shall consider first the effect of the moment M at the several points of this arch.

The moment M produces strains of the same absolute value above and below the neutral axis, compressive on one side, and tensile on the other side of the axis. There results a deflection of the centre line, and hence M is called the *moment of flexure.*

If we put

δ=the angle which the normal at O makes with a vertical line *before* flexure,

δ_1=the angle which the normal at O makes with a vertical line *after* flexure,

R=the radius of curvature *before* flexure,

R_1=the radius of curvature *after* flexure,

s=the arc A O,

ds=the infinitesimal element of the arc s,

θ=the moment of inertia of the normal section of the arch, the condition that the length of the center line, or arc A O, is not changed by the flexure, gives

6. $ds=-R\,d\,\delta=-R_1\,d\,\delta_1$.

The arch being conceived to be composed of fibers of infinitesimal thickness, lying in the direction of the curve, the position of any fiber may be expressed by coordinates u and v, the axis of u being a horizontal line through O perpendicular to the vertical plane of the arch, and the axis of v being the normal line at O, or intersection of the normal and vertical planes at this point.

We shall assume that the axis of u is the *neutral axis.*† The condition that the normal section H N remains normal to the curve A O at O, during flexure, requires that fibers at different distances from the neutral axis should be compressed or elongated by quantities proportional to those distances, that is, proportional to the values of v. Conceiving, therefore, two consecutive normal planes to be drawn, the length of the infinitesimal portion, or element of any fibre intercepted between these two planes, will be before flexure $ds+v\,d\,\delta$, and after flexure $ds+v\,d\,\delta_1$; the element has therefore been increased in length by $(d\,\delta_1-d\,\delta)\,v$. If then

ε = the modulus of elasticity of the material composing the arch,

$du,\ dv$ will be the area of the section of the fiber, and $\varepsilon.\ du,\ dv$ will be the force necessary to elongate the element $ds+v\,d\,\delta$ by its own length; and hence the force necessary to elongate it by the quantity $(d\,\delta_1-d\,\delta)\,v$ will be

$$\frac{(d\,\delta_1-d\,\delta)\,v}{ds+v\,d\,\delta}.\ \varepsilon.\ du,\ dv,$$

or substituting $R\,d\,\delta$ for ds,

$$\frac{d\,\delta_1-d\delta}{d\,\delta}.\ \varepsilon.\ \frac{du\,dv\,v}{R+v}$$

And the moment of this force about the neutral axis is the force multiplied by v, *i. e.*,

$$\frac{d\delta_1-d\,\delta}{d\,\delta}.\ \varepsilon.\ \frac{du\,dv\,v^2}{R+v}$$

The total moment M of all the fibers is, therefore,

$$M=\frac{d\,\delta_1-d\,\delta}{d\,\delta}.\ \varepsilon.\int\int\frac{du dv\,v^2}{R+v},$$

* The influence of this force will be considered afterwards. See page 495.

† For a straight prismatic beam this assumption is exact, and it is sufficiently correct for a curved beam whose radius is very great in comparison with its thickness.

the limits of the integrals being determined by the form of the normal section.

The figure of the normal section being symmetrical with respect to the neutral axis, the values of $\frac{du\,dv\,v^2}{R+v}$ at equal distances, above and below this axis, will be

$$\frac{dv\,do\,v^2}{R+v} \text{ and } \frac{du\,dv\,v^2}{R-v}$$

whose sum is

$$\frac{2}{R}\cdot\frac{du\,dv\,v^2}{1-\frac{v^2}{R^2}}.$$

As it is assumed that the vertical thickness of the arch is small compared with the radius, $\frac{v^2}{R^2}$ will be the square of a small fraction, hence no appreciable error is committed in taking the integral by omitting this fraction,* and we may take

$$M=\frac{d\delta_1-d\delta}{d\delta}\cdot\frac{\varepsilon}{R}\cdot\int\int du\,dv\,v^2$$

The integral $\int\int du\,dv\,v^2$ is simply the *moment of inertia* of the normal section of the arch, and by substituting for it the letter θ, we obtain the equation

$$7.\quad d\delta_1-d\delta=\frac{RM}{\varepsilon\theta}\,d\delta.$$

In applying this equation to our arch, we shall assume θ as constant.†

As the internal forces in any section F, considered as acting on the portion A F of the arch, have to be in equilibrium with the external forces acting on the same portion of the arch, the moment M of the internal forces around F must be equal to the moment of the external forces for the same point. This gives us the equations

a/ for loaded part, from $x=o$ to $x=n\,a$,

$$M=q\frac{x^2}{2}-P(x-b\sin.\alpha)+Q\,(y+b\cos.\alpha)$$

or by 1, and by introducing

$$8.\quad C=\frac{b}{R}$$

$$9a\quad M=-PR\,[(1-c)\sin.\alpha-\sin.\delta]+QR\,[\cos.\delta-(1-c)\cos.\alpha] + \frac{qR^2}{2}\,(\sin.\alpha-\sin.\delta)^2\ ;$$

b/ for unloaded part, from $x=n\,a$ to $x=2a$.

$$M=-P\,(x-b\sin.\alpha)+Q\,(y+b\cos.\alpha)$$
$$q\,n\,a\left(x-\frac{n.a}{2}\right)$$

or by 1 and 8,

$$9b.\quad M=-PR\,[(1-c)\sin.\alpha-\sin.\delta]+QR\,[\cos.\delta-(1-c)\cos.\alpha] -q\,R^2\sin.\delta\,(\sin\alpha-\sin.\beta)+\frac{qR^2}{2}\,(\sin.^2\alpha-\sin.^2\beta).$$

Substituting these values of M in equation 7 and integrating,* we obtain

a/ for loaded part,

$$10a.\quad \delta_1-\delta=\frac{R^2}{\varepsilon\theta}\left(\left\{-P(1-c)\sin.\alpha-Q\,(1-c)\cos.\alpha+\frac{qR}{2}\sin.^2\alpha+\frac{qR}{4}\right\}\delta-(P-qa)\cos.\delta+Q\sin.\delta-\frac{qR}{4}\sin.\delta\cos.\delta+A\right)$$

b/ for unloaded part,

$$10b.\quad \delta_1-\delta=\frac{R^2}{\varepsilon\theta}\left(\left\{-P\,(1-c)\sin.\alpha-Q(1-c)\cos.\alpha+\frac{qR}{2}\sin.^2\alpha-\frac{qR}{2}\sin.^2\beta\right\}\delta-(P-q\,a+qR\sin.\beta)\cos.\delta+Q\sin.\delta+B\right)$$

in which A and B are constants of integration.

For $\delta=\beta$ the equations (10a) and (10b) must be identical, which furnishes the equation

* For the middle span of the Illinois and St. Louis Bridge we have $R=736$ feet, and the mean value of $v=6$ feet. The fraction $\frac{v^2}{R^2}$ is therefore $\frac{1}{15129}$, and the error committed by omitting this fraction will be less than $\frac{7}{1000}$ of one per cent.

† In practice the variations in the cross-section of the arch will not be very great, and, by assuming the cross-section to be constant, we may arrive at a very close approximation to the real values of the resistances at the abutments without knowing the value of θ. It will, however, be shown hereafter (see page 496) how variations of the cross-sections may be considered.

* Employing the known integrals

$$\int d\delta\sin.\delta=-\cos.\delta,$$
$$\int d\delta\cos.\delta=\sin.\delta,$$
$$\int d\delta\sin.^2\delta=\tfrac{1}{2}\,(\delta-\sin.\delta\cos.\delta).$$

$$11\begin{cases} A-B=-\frac{qR}{4}(\beta+2\,\beta\sin.^2\beta+3\sin.\\ \beta\cos.\beta)=-\frac{qR}{4}\mu,\\ \text{if }\mu=\beta+2\,\beta\sin.^2\beta+3\sin.\beta\cos.\beta. \end{cases}$$

Now, since we have for the undeflected arc s and the deflected arc s_1

$$d\,x=d\,s\cos.\delta,\qquad d\,x_1=d\,s_1\cos.\delta_1,$$
$$d\,y=d\,s.\sin.\delta,\qquad d\,y_1=d\,s_1\sin.\delta_1,$$

and $d\,s=d\,s_1=-R\,d\,\delta$, there follows very nearly*

$$d\,x_1-d\,x=-Rd\,\delta\,(\cos.\delta_1-\cos.\delta)=Rd\delta\,(\delta_1-\delta)\sin.\delta,$$
$$d\,y_1-d\,y=-R\,d\,\delta\,(\sin.\delta_1-\sin.\delta)=-R\,d\,\delta\,(\delta_1-\delta)\cos.\delta.$$

Hence, multiplying the equation (10) by $R\,d\,\delta\sin.\delta$, or $-R\,d\,\delta\cos.\delta$, and integrating,† introducing at the same time the auxiliaries,

$$12\begin{cases} G=-P\,(1-c)\sin.\alpha-Q\,(1-c)\cos.\\ \alpha+\frac{qR}{2}\sin.^2\alpha+\frac{qR}{8}-\frac{qR}{4}\sin.^2\beta,\\ H=\frac{qR}{4}+\frac{qR}{4}\sin.^2\beta, \end{cases}$$

We find for the different parts of the arch the horizontal and vertical deflections

$$13a/\;x_1-x=\frac{R^3}{\varepsilon\,\theta}\Big\{(G+H)\,(\sin.\delta-\delta\cos.\delta)-(P-qa)\frac{\sin.^2\delta}{2}+Q\frac{\delta-\sin.\delta\cos.\delta}{2}-\frac{qR}{12}\sin.^3\delta-A\cos.\delta+C\Big\}$$

$$13b/\;x_1-x=\frac{R^3}{\varepsilon\,\theta}\Big\{(G-H)\,(\sin.\delta-\delta\cos.\delta)-(P-qa+qR\sin.\beta)\frac{\sin.^2\delta}{2}+Q\frac{\delta-\sin.\delta\cos.\delta}{2}-B\cos.\delta+D\Big\}$$

$$14a/\;y_1-y=\frac{R^3}{\varepsilon\,\theta}\Big\{-(G+H)\,(\cos.\delta+\delta\sin.\delta)+(P-qa)\frac{\delta+\sin.\delta\cos.\delta}{2}-Q\frac{\sin.^2\delta}{2}-\frac{qR}{12}\cos.^3\delta-A\sin.\delta+E\Big\}$$

$$14b/\;y_1-y=\frac{R^3}{\varepsilon\,\theta}\Big\{-(G-H)\,(\cos.\delta+\delta\sin.\delta)+(P-qa+qR\sin.\beta)\frac{\delta+\sin.\delta\cos.\delta}{2}-Q\frac{\sin.^2\delta}{2}-B\sin.\delta+F\Big\}$$

The equations $13a$ and $13b$ must be identical for $\delta=\beta$. This gives us the relation

$$C-D=-2\,H\,(\sin.\beta-\beta\cos.\beta)-qR\frac{\sin.^3\beta}{2}+qR\frac{\sin.^3\beta}{12}+(A-B)\cos.\beta$$

Substituting the values of H (from 12) and of (A—B) (from 11), we find

$$15\begin{cases} C-D=-qR\left(\sin.\beta+\frac{\sin.^3\beta}{6}\right)=-qR\,\nu,\text{ if}\\ \nu=\sin.\beta+\frac{\sin.^3\beta}{6} \end{cases}$$

In a similar manner we obtain from the condition that also equations $14a$ and $14b$ must be identical for $\delta=\beta$, the relation

$$16\begin{cases} E-F=qR\left\{\frac{\cos.\beta}{2}+\frac{\beta\sin.\beta}{2}-\frac{\cos.^3\beta}{6}\right\}=qR\,\xi,\text{ if}\\ \xi=\frac{\cos.\beta}{2}+\frac{\beta\sin.\beta}{2}-\frac{\cos.^3\beta}{6} \end{cases}$$

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* $\cos.\delta_1-\cos.\delta=-2\sin.\frac{\delta_1+\delta}{2}\sin.\frac{\delta_1-\delta}{2}$; $\sin.\delta_1-\sin.\delta=2\sin.\frac{\delta_1-\delta}{2}.\cos.\frac{\delta_1+\delta}{2}$.

The deflection of the arch being very slight, the angles δ_1 and δ will be very nearly equal, hence we may assume

$\frac{\delta_1+\delta}{2}=\delta$, and $\sin.\frac{\delta_1-\delta}{2}=\frac{\delta_1-\delta}{2}$ and now $\cos.\delta_1-\cos.\delta=-(\delta_1-\delta)\sin.\delta$, and $\sin.\delta_1-\sin.\delta=(\delta_1-\delta)\cos.\delta$.

† Employing the known integrals already used, and also

$$\int d\,\delta.\,\delta\sin.\delta=\sin.\delta-\delta\cos.\delta$$
$$\int d\,\delta.\sin.\delta\cos.\delta=\tfrac{1}{2}\sin.^2\delta$$
$$\int d\,\delta.\sin.^2\delta\cos.\delta=\tfrac{1}{3}\sin.^3\delta$$
$$\int d\,\delta.\,\delta\cos.\delta=\cos.\delta+\delta\sin.\delta$$
$$\int d\,\delta\cos.^2\delta=\tfrac{1}{2}(\delta+\sin.\delta\cos.\delta)$$
$$\int d\,\delta\cos.^2\delta\sin.\delta=-\tfrac{1}{3}\cos.^3\delta$$

The equations 13*a* and 13*b* must give $x_1-x=0$ for $\delta=+\alpha$ or $\delta=-\alpha$. These values of δ substituted, and the equations subtracted, gives with the values of A−B from 11, and of C−D from 15, the equation

17. $$0=2\,G\,(\sin.\alpha-\alpha\cos.\alpha)+q\,R\,\frac{\sin.^2\alpha}{2}\sin.\beta+Q\,(\alpha-\sin.\alpha\cos.\alpha)-q\,R\frac{\sin.^3\alpha}{12}+\frac{qR}{4}\mu\cos.\alpha-q\,R\,\nu.$$

The equations 14*a* and 14*b* must give $y_1-y=0$ for $\delta=+\alpha$ or $\delta=-\alpha$. By subtracting the equations, after substituting $+\alpha$ or $-\alpha$ for δ, we obtain

18. $$0=-2\,H\,(\cos.\alpha+\alpha\sin.\alpha)+\left(P-q\,a+q\,R\frac{\sin.\beta}{2}\right)(\alpha+\sin.\alpha\cos.\alpha)-q\,R\frac{\cos.^3\alpha}{12}-(A-B)\sin.\alpha+q\,R\,\xi.$$

Adding equation 13*a*, with $\delta=+\alpha$, and 13*b* with $\delta=-\alpha$, we obtain

19. $$C+D=-2\,H\,(\sin.\alpha-\alpha\cos.\alpha)+\left(P-q\,a+\frac{q\,R\sin.\beta}{2}\right)\sin.^2\alpha+\frac{q\,R}{12}\sin.^3\alpha+(A+B)\cos.\alpha.$$

Adding equation 14*a* with $\delta=+\alpha$, and 14*b* with $\delta=-\alpha$, we obtain

20. $$E+F=2\,G\,(\cos.\alpha+\alpha\sin.\alpha)+Q\sin.^2\alpha+\frac{q\,R}{2}\sin.\beta\,(\alpha+\sin.\alpha\cos.\alpha)+\frac{q\,R}{12}\cos.^3\alpha+(A-B)\sin.\alpha.$$

Equations (17) and (18) contain besides P and Q only the unknown quantity (A+B). In order to find a third equation, which would enable us to determine these values, we have to consider the peculiar manner in which the ends of the arch are connected with, or pressing against the abutments. We shall consider the following distinct cases:

I. Both ends of the arch are firmly held to the abutments in such a manner that the tangents to the arch at the ends cannot change their direction.

II. The arch is firmly held at the loaded end and resting with the unloaded end on a pivot.

III. The arch rests with the loaded end on a pivot and is firmly held at the unloaded end.

IV. Both ends of the arch rest on pivots.

If in cases II, III and IV the pivots are $\left\{\begin{matrix}\text{below}\\ \text{in}\\ \text{above}\end{matrix}\right\}$ the centre line of the arch, b or b_1 will be $\left\{\begin{matrix}\text{positive}\\ 0\\ \text{negative}\end{matrix}\right\}$

I. ARCH FIRMLY HELD AT BOTH ENDS.

Equation 10*a* must give $\delta_1-\delta=0$ for $\delta=\alpha$, and equation 10*b* must give $\delta_1-\delta=0$ for $\delta=-\alpha$. Both equations subtracted give, if we substitute at the same time the value for A−B by 11, and using the auxiliary G by (12)

$$0=2\,G\,\alpha+q\,R\cos.\alpha\sin.\beta+2\,Q\sin.\alpha-q\frac{R}{4}\sin.\alpha\cos.\alpha-\frac{qR}{4}\mu \text{ or}$$

I*a*. $$G=-Q\frac{\sin.\alpha}{\alpha}+q\frac{R}{8}\frac{\sin.\alpha\cos.\alpha}{\alpha}-\frac{q\,R}{2}\frac{\cos.\alpha}{\alpha}\sin.\beta+\frac{q\,R}{8\alpha}\mu$$

Substituting the value of G in equation 17, and introducing the auxiliaries

I*b*. $$\left\{\begin{aligned} K&=\alpha+\sin.\alpha\cos.\alpha-\frac{2\sin.^2\alpha}{\alpha}\\ K_1&=\frac{\sin.^3\alpha}{12}-\frac{\sin.\alpha\cos.\alpha}{4\alpha}(\sin.\alpha-\alpha\cos.\alpha)\\ K_2&=\frac{\sin.^2\alpha}{2}-\frac{\cos.\alpha}{\alpha}(\sin.\alpha-\alpha\cos.\alpha)\end{aligned}\right.$$

We obtain for the Q the equation

I*c*. $$Q=\frac{q\,R}{K}\left\{K_1-K_2\sin.\beta-\frac{\sin.\alpha}{4\alpha}\mu+\nu\right\}$$

(For μ and v, see equations 11 and 15.)

By adding the equations 10*a* with $\delta=\alpha$, and 10*b* with $\delta=-\alpha$, we obtain

I*d*. $$0=2\,H\,\alpha-2\,\left(P-q\,R\sin.\alpha+\frac{q\,R}{2}\sin.\beta\right)\cos.\alpha-\frac{q\,R}{4}\sin.\alpha\cos.\alpha+(A+B)$$

And if we multiply this equation by sin. α, and add it to equation 18, substituting at the same time for H its value by 12, and using the auxiliaries,

I*e*. $$\left\{\begin{aligned} K'_1&=\sin.\alpha+\frac{2\cos.\alpha+\cos.\alpha\sin.^2\alpha}{6\,(\alpha-\sin.\alpha\cos.)\alpha}\\ K'_2&=\frac{\cos.\alpha}{2\,(\alpha-\sin.\alpha\cos.\alpha)},\\ K'_3&=\frac{1}{\alpha-\sin.\alpha\cos\alpha},\end{aligned}\right.$$

we find

$$\text{I}f.\ P = qR\left\{K'_1 - \frac{\sin.\beta}{2} + K'_2 \sin.^2\beta - K'_3 \xi\right\}$$

(for ξ see equation 16).

Let us now substitute for G in I*a* its value by 12, and for C its value $\left(=\frac{b}{R}\right)$ by 8, and we obtain

$$\text{I}g.\ b(P\sin.\alpha + Q\cos.\alpha) = PR\sin.\alpha + QR\left(\cos.\alpha - \frac{\sin.\alpha}{\alpha}\right)$$
$$-\frac{qR^2}{8\alpha}(\alpha - \sin.\alpha\cos.\alpha + 4\alpha\sin.^2\alpha) -$$
$$\frac{qR^2}{2\alpha}\cos.\alpha\sin.\beta + \frac{qR^2}{4}\sin.^2\beta + \frac{qR^2}{8\alpha}\mu$$

After Q and P, the horizontal and vertical resistances of the abutment, have been computed by I*e* and I*f*, we can compute b (P sin. α + Q cos. α), the moment of flexure produced by the resistance of the abutment, by equation I*g*. The resistances of the abutment at the other end of the arch P_1, Q_1 and b_1 ($P_1 \sin.\alpha + Q_1 \cos.\alpha$) may then be computed by equations 3, 4 and 5.

For the case of a load extending uniformly over the whole span ($\beta = -\alpha$), the formulæ I*c*, I*f* and I*g* may be simplified

$$\text{I}c'\ Q = \frac{qR}{K}.2K_1$$

$$\text{I}f'\ P = qR\sin.\alpha$$

$$\text{I}g'\ b(P\sin.\alpha + Q\cos.\alpha) = QR\left(\cos.\alpha - \frac{\sin.\alpha}{\alpha}\right)$$
$$+ qR^2\left(-\tfrac{1}{4} + \frac{\sin.^2\alpha}{2} + \frac{\sin.\alpha\cos.\alpha}{4\alpha}\right)$$

To compute the horizontal and vertical deflections of the arch, we have first to determine the constants A B C D E and F. The values of A—B, C—D and E—F, are known by the equations 11, 15 and 16.

(A+B) can be determined by I*d*; (C+D) and (E+F) by 19 and 20.

The values of (A—B) and (A+B), (C—D) and (C+D), (E—F) and (E+F) being known, the values of A B C D E and F are easily found, and then the horizontal and vertical deflections can be computed by the equations 13 and 14.

II. ARCH FIRMLY HELD AT THE LOADED END, AND THE UNLOADED END RESTING ON A PIVOT.

The centre of the pivot will in this case be the point H of our Fig. 1, and hence b_1 will be a known quantity. Substituting the values of P_1 and Q_1 by 3 and 4 in equation 5, and dividing the equation by R, we obtain

$$\frac{b_1}{R}(-P\sin.\alpha + Q\cos.\alpha + qna\sin.\alpha) =$$
$$\frac{b}{R}(P\sin.\alpha + Q\cos.\alpha) - 2P\sin.\alpha$$
$$+ 2qna\sin.\alpha - qn^2a\frac{\sin.\alpha}{2}$$

If we add P sin. α + Q cos. α on each side of the equation sign, and put

$$\tau = 1 - \frac{b}{R} = 1 - C; \qquad \tau_1 = 1 - \frac{b_1}{R} = 1 - C_1,$$

Substituting also R sin. α for a, and $\frac{\sin.\alpha - \sin.\beta}{\sin.\alpha}$ for n, we find

$$\text{II}a/\ \tau(P\sin.\alpha + Q\cos.\alpha) = \tau_1(-P\sin.\alpha + Q\cos.\alpha + qR\sin.^2\alpha - qR\sin.\alpha\sin.\beta) + qR\frac{\sin.^2\alpha}{2} - \frac{qR\sin.^2\beta}{2}.$$

As the arch is firmly held at the loaded end, equation 10*a* must give $\delta_1 - \delta = 0$ for $\delta = \alpha$. Introducing further for τ(P sin. α + Q cos. α) in 10*a* the value by equation II*a*, we obtain

$$\text{II}b.\ A = P[\cos.\alpha - \tau_1\alpha\sin.\alpha] + Q[-\sin.\alpha + \tau_1\alpha\cos.\alpha] + qR[-\tfrac{3}{4}\sin.\alpha\cos.\alpha - \frac{\alpha}{4} + \tau_1\alpha\sin.^2\alpha] - qR\tau_1\alpha\sin.\alpha\sin.\beta - \frac{qR}{2}\alpha\sin.^2\beta,$$

further

A+B=2 A—(A—B) or by II*b* and 11

$$\text{II}c.\ A + B = P[2\cos.\alpha - 2\tau_1\alpha\sin.\alpha] + Q[-2\sin.\alpha + 2\tau_1\alpha\cos.\alpha]$$
$$+ qR\left(-\frac{3}{2}\sin.\alpha\cos.\alpha - \frac{\alpha}{2} + 2\tau_1\alpha\sin.^2\alpha\right)$$
$$-2qR\tau_1\alpha\sin.\alpha\sin.\beta - qR\alpha\sin.^2\beta + \frac{qR}{4}\mu.$$

With this value of A+B, and by putting

$$\text{II}d. \begin{cases} t = \alpha - \sin.\alpha \cos.\alpha + 2\,\tau_1 \alpha \sin.^2\alpha \\ t_1 = 2 \sin.^2\alpha - 2\,\tau_1\,\alpha \sin.\,\alpha \cos.\,\alpha \\ t_2 = \dfrac{\sin.^2\alpha \cos.\alpha}{4} - \frac{3}{4}\,\alpha \sin.\,\alpha - \dfrac{\cos.^3\alpha}{3} - 2\,\tau_1\,\alpha \sin.^3\alpha \\ t_3 = \dfrac{\alpha}{2} + \dfrac{\sin.\alpha \cos.\alpha}{2} + 2\tau_1 \alpha \sin.^3\alpha \\ t_4 = -\dfrac{\cos.\,\alpha}{2} + \dfrac{\alpha \sin.\,\alpha}{2} \end{cases}$$

We obtain from equation 18,

$$\text{II}e.\ 0 = P\,t + Q\,t_1 + q\,R \left\{ t_2 + t_3 \sin.\,\beta + t_4 \sin.^2\beta - \frac{\sin.\alpha}{4}\,\mu + \xi \right\}$$

If we substitute the value of τ (P sin.α + Q cos. α) by IIa. in the first of equation 12 we obtain

$$\text{II}f.\ G = -\tau_1\,(-P \sin.\alpha + Q \cos.\alpha + q\,R \sin.^2\alpha - q\,R \sin.\alpha \sin.\,\beta) + \frac{q\,R}{8} + \frac{q\,R \sin.^2\beta}{4}$$

and now by 17 and with the auxiliaries

$$\text{II}g. \begin{cases} \delta = 2\,\tau_1 \sin.\alpha\,(\sin.\alpha - \alpha \cos.\alpha) \\ \delta_1 = \alpha - \sin.\,\alpha \cos.\,\alpha - 2\,\tau_1 \cos.\,\alpha\,(\sin.\,\alpha - \alpha \cos.\,\alpha) \\ \delta_2 = -\dfrac{\sin.^3\alpha}{12} + \dfrac{\sin.\,\alpha - \alpha \cos.\,\alpha}{4} - 2\,\tau_1 \sin.^2\alpha\,(\sin.\alpha - \alpha \cos.\alpha) \\ \delta_3 = \dfrac{\sin.^2\alpha}{2} + 2\,\tau_1 \sin.\alpha\,(\sin.\,\alpha - \alpha \cos.\,\alpha) \\ \delta_4 = \dfrac{\sin.\,\alpha - \alpha \cos.\,\alpha}{2} \end{cases}$$

$$\text{II}h.\ 0 = P\,\delta + Q\,\delta_1 + q\,R \left\{ \delta_2 - \delta_3 \sin.\,\beta + \delta_4 \sin.^2\beta + \frac{\cos.\alpha}{4}\mu - v \right\}$$

Let us now put

$$\text{II}i. \begin{cases} K = t\,\delta_1 - t_1\,\delta \\ K_1 = t_1\,\delta_2 - t_2\,\delta_1 & K'_1 = \delta\,t_2 - \delta_2\,t \\ K_2 = t_1\,\delta_3 - t_3\,\delta_1 & K'_2 = \delta\,t_3 - \delta_3\,t \\ K_3 = t_1\,\delta_4 - t_4\,\delta_1 & K'_3 = \delta\,t_4 - \delta_4\,t \\ K_4 = t_1 \dfrac{\cos.\,\alpha}{4} + \dfrac{\sin.\,\alpha}{4}\,\delta_1 & K'_4 = \delta \left(-\dfrac{\sin.\,\alpha}{4}\right) - \dfrac{\cos.\,\alpha}{4}\,t \end{cases}$$

And the two equations, IIe. and IIh., will give us

$$\text{II}j.\ P = \frac{q\,R}{K}\,[K_1 + K_2 \sin.\,\beta + K_3 \sin.^2\beta + K_4\,\mu - t_1\,\nu - \delta_1\,\xi]$$

$$\text{II}k.\ Q = \frac{q\,R}{K}\,[K'_1 + K'_2 \sin.\,\beta + K'_3 \sin.^2\beta + K'_4\,\mu + t\,\nu + \delta\,\xi]$$

P and Q being found, we obtain P_1 and Q_1 by 3 and 4 and then b or the moment b (P sin. α + Q cos. α) by 5.

The constants A B C D E and F required for the computation of the deflection will be obtained from the values of (A − B), (C − D) and (E − F) by 11, 15 and 16, and those of (A + B), (C + D) and (E + F) by (IIc) 19 and 20.

III. ARCH FIRMLY HELD AT UNLOADED END, AND THE LOADED END RESTING ON A PIVOT.

G Fig. 1 will be the centre of the pivot, hence b is a known quantity.

The arch being firmly held at the unloaded end, equation 10b must give $\delta_1 - \delta = 0$ for $\delta = -\alpha$, and putting $\tau = 1 - c$ we obtain

$$\text{III}a.\ B = P\,(\cos.\,\alpha - \tau\,\alpha \sin.\,\alpha) + Q\,(\sin.\alpha - \tau\,\alpha \cos.\,\alpha) + q\,R \left(\frac{\alpha \sin.^2\alpha}{2} - \sin.\alpha \cos.\,\alpha\right) + q\,R \sin.\,\beta \cos.\,\alpha - \frac{q\,R}{2}\,\alpha \sin.^2\beta$$

We find further from $A + B = (A - B) + 2\,B = 2\,B - \frac{q\,R}{4}\,\mu$

$$\text{III}b.\ A + B = 2\,P\,(\cos.\alpha - \tau\,\alpha \sin.\,\alpha) + 2\,Q \sin.\,\alpha - \tau\,\alpha \cos.\,\alpha) + q\,R\,(\sin.^2\alpha - 2 \sin.\,\alpha \cos.\,\alpha) + 2\,q\,R \sin.\,\beta \cos.\,\alpha - q\,R\,\alpha \sin.^2\beta - \frac{q\,R}{4}\,\mu.$$

Substituting this value in 18, and putting

$$\text{III}c. \begin{cases} t = \alpha - \sin.\alpha \cos.\alpha + 2\,\tau\,\alpha \sin.^2\alpha \\ t_1 = -2 \sin.^2\alpha + 2\,\tau\,\alpha \sin.\alpha \cos.\alpha \\ t_2 = -\dfrac{\cos.\alpha}{4} - \dfrac{5}{4}\,\alpha \sin\,\alpha - \dfrac{\cos.^3\alpha}{12} + \sin.^2\alpha \cos.\,\alpha - \alpha \sin.^3\alpha \\ t_3 = \dfrac{\alpha}{2} - \dfrac{3}{2} \sin.\,\alpha \cos.\,\alpha \\ t_4 = -\dfrac{\cos.\,\alpha}{2} + \dfrac{\alpha \sin.\,\alpha}{2} \end{cases}$$

we obtain

IIId. $0 = Pt + Qt_1 + qR\left(t_2 + t_3 \sin.\beta + t_4 \sin.^2\beta + \frac{\sin.\alpha}{4}\mu + \xi\right)$

If we substitute in 17 the value of G by 12, and put

$$\text{IIIe.}\begin{cases} \delta = -2\tau \sin.\alpha\,(\sin.\alpha - \alpha\cos.\alpha) \\ \delta_1 = -2\tau\cos.\alpha\,(\sin.\alpha - \alpha\cos.\alpha) + \alpha - \sin.\alpha\cos.\alpha \\ \delta_2 = (\frac{1}{4} + \sin.^2\alpha)(\sin.\alpha - \alpha\cos.\alpha) - \frac{\sin.^3\alpha}{12} \\ \delta_3 = \frac{\sin.^2\alpha}{2} \\ \delta_4 = -\frac{1}{2}\sin.\alpha - \alpha\cos.\alpha \end{cases}$$

we obtain

IIIf. $0 = P\delta + Q\delta_1 + qR\left\{\delta_2 + \delta_3\sin.\beta + \delta_4\sin.^2\beta + \frac{\cos.\alpha}{4}\mu - \nu\right\}$

Putting now

$$\text{IIIg.}\begin{cases} K = t\delta_1 - t_1\delta \\ K_1 = t_1\delta_2 - t_2\delta_1 \qquad K'_1 = \delta t_2 - \delta_2 t \\ K_2 = t_1\delta_3 - t_3\delta_1 \qquad K'_2 = \delta t_3 - \delta_3 t \\ K_3 = t_1\delta_4 - t_4\delta_1 \qquad K'_3 + \delta t_4 - \delta_4 t \\ K_4 = \frac{\cos.\alpha}{4}t_1 - \frac{\sin.\alpha}{4}\delta_1 \qquad K'_4 = \delta\frac{\sin.\alpha}{4} - \frac{\cos.\alpha}{4}t, \end{cases}$$

we find by IIId and IIIf.

IIIh. $P = \frac{qR}{K}[K_1 + K_2\sin.\beta + K_3\sin.^2\beta + K_4\mu - t_1\nu + \delta_1\xi]$

IIIi. $Q = \frac{qR}{K}[K'_1 + K'_2\sin.\beta + K'_3\sin.^2\beta\ K'_4\mu + t\nu + \delta\xi]$

P and Q once known, we obtain P_1, Q_1, and b_1 ($P_1 \sin.\alpha + Q_1\cos.\alpha$) by 3, 4 and 5.

The constants A, B, C, D, E and F are obtained by 11, 15, 16, III*b*., 19 and 20.

IV. BOTH ENDS OF THE ARCH PIVOTED, OR b AND b_1 KNOWN.

If we substitute in 5 for P_1 Q_1 and na their values by 3, 4 and 1, we obtain

$$P\sin.\alpha(-b_1 - b + 2R) = Q\cos.\alpha(b - b_1) + qR\sin.^2\alpha(-b_1 + \tfrac{3}{2}R) + qR\sin.\beta\sin\alpha(b_1 - R) - \frac{qR^2\sin.^2\beta}{2};$$

and putting

IVa. $\tau = 1 - c = 1 - \frac{b}{R}$; $\tau_1 = 1 - c_1 = 1 - \frac{b_1}{R}$;

we find

IVb. $P\sin.\alpha = Q\cos.\alpha\frac{\tau_1 - \tau}{\tau + \tau_1} + qR\sin.^2\alpha\frac{1 + 2\tau_1}{2(\tau + \tau_1)} - qR\sin.\beta\sin.\alpha\frac{\tau_1}{\tau + \tau_1} - \frac{qR\sin.^2\beta}{2(\tau + \tau_1)}$

Equation 12 becomes with this value of P sin. α,

IVc. $G = -Q\cos.\alpha\frac{2\tau\tau_1}{\tau + \tau_1} + \frac{qR}{8} + \frac{qR\sin.^2\alpha}{2}\cdot\frac{\tau_1 - 2\tau\tau_1}{\tau + \tau_1} + qR\sin.\alpha\sin.\beta\frac{\tau\tau_1}{\tau + \tau_1} + \frac{qR\sin.^2\beta}{4}\frac{\tau - \tau_1}{\tau + \tau_1}$,

and now by 17 and with the auxiliaries,

IVd. $\tau_2 = \frac{\tau}{\tau + \tau_1}$; $\tau_3 = \frac{\tau_1}{\tau + \tau_1}$; $\tau_4 = \frac{\tau\tau_1}{\tau + \tau_1}$

$$\text{IVe.}\begin{cases} K = -4\tau_4\cos.\alpha\,(\sin.\alpha - \alpha\cos.\alpha) + \alpha - \sin.\alpha\cos.\alpha \\ K_1 = -(\sin.\alpha - \alpha\cos.\alpha)[\frac{1}{4} + \sin.^2\alpha(\tau_3 - 2\tau_4)] + \frac{\sin.^3\alpha}{12} \\ K_2 = -\frac{\sin.^2\alpha}{2} - 2\sin.\alpha\,(\sin.\alpha - \alpha\cos.\alpha)\,\tau_4 \\ K_3 = \frac{1}{2}(\sin.\alpha - \alpha\cos.\alpha)(\tau_3 - \tau_2) \end{cases}$$

IVf. $Q = \frac{qR}{K}\left\{K_1 + K_2\sin.\beta + K_3\sin.^2\beta - \frac{\cos.\alpha}{4}\mu + \nu\right\}$

P will be obtained by substituting the value of Q by IV*f* in IV*b*.

The constants A, B, C, D, E and F for the computation of the deflections can be computed from the values of A−B, C−D, E−F', by 11, 15 and 16, and of A+B by 18, C+D by 19, and E + F by 20.

In the particular case (IV') when both pivots are in the centre-line of the arch, or $b = b_1 = 0$, the auxiliaries become

IV'a. $\tau' = \tau'_1 = 1$

IV'd. $\tau'_2 = \tau'_3 = \tau'_4 = \frac{1}{2}$

$$\text{IV}'e.\ \begin{cases} K' = 3\,(\alpha - \sin.\,\alpha\cos.\,\alpha) - 2\,\alpha\sin.^2\alpha \\ K'_1 = -\tfrac{1}{4}\,(\sin.\,\alpha\cos.\,\alpha)\,(1 - 2\sin.^2\alpha) + \dfrac{\sin.^3\alpha}{12} \\ K'_2 = -\tfrac{3}{8}\sin.^2\alpha + \alpha\sin.\,\alpha\cos.\,\alpha \\ K'_3 = 0 \end{cases}$$

We can further in this case compute P directly by 5, which becomes with $b=b_1=0$.

$$\text{IV}'g.\quad P = q\,n\,a\left(1 - \frac{n}{4}\right)$$

EFFECT OF CHANGES OF TEMPERATURE UPON THE ARCH.

If λ is the coefficient of expansion for a given change of temperature, the resistances of the abutments created by that change may be considered as the forces which, applied to the freely expanded arch of the span $2a\,(1+\lambda)$, would force it back to the original span $2a$. The coefficient λ being a very small fraction, we may also, very approximately, regard the resistances spoken of, as the forces which would reduce the span $2a$ of the arch for the length $2\,\lambda\,a$. As in the investigation of the effect of load, we may assume these forces to consist of vertical and horizontal forces P, Q, and P_1, Q_1, acting on points G and H in the normal end-planes of the arch (Fig. 1).

The conditions for the equilibrium of the arch are

21. $P_1 = -P$

22. $Q_1 = Q$

23. $b_1\,(P_1\sin.\,\alpha + Q_1\cos.\,\alpha) = b\,(P\sin.\,\alpha + Q\cos.\,\alpha) - 2\,Pa.$

The moment of flexure for any point F will be

$$M = -P\,(x - b\sin.\,\alpha) + Q\,(y + b\cos.\,\alpha)$$

or by $x = R\,(\sin.\,\alpha - \sin.\,\delta)$; $y = R\,(\cos.\,\delta - \cos.\,\alpha)$; and $1 - \dfrac{b}{R} = \tau$;

24. $M = -P\,R\,(\tau\sin.\,\alpha - \sin.\,\delta) + Q\,R\,(\cos.\,\delta - \tau\cos.\,\alpha).$

Substituting this value of M in equation 7, and integrating, we obtain

25. $\delta_1 - \delta = \dfrac{R^2}{2\,\theta}\,[-\tau\,(P\sin.\,\alpha + Q\cos.\,\alpha)\,\delta - P\cos.\,\delta + Q\sin.\,\delta + A]$

Multiplying 25 by $R\,d\,\delta\sin.\,\delta$ or $-R\,d\,\delta\cos.\,\delta$, and integrating, we reduce as on page 486,

26. $x_1 - x = \dfrac{R^3}{\xi\,\theta}\left\{-\tau(P\sin.\,\alpha + Q\cos.\,\alpha)(\sin.\,\delta - \delta\cos.\,\delta) - P\,\dfrac{\sin.^2\delta}{2} + Q\,\dfrac{\delta - \sin.\,\delta\cos.\,\delta}{2} - A\cos.\,\delta + C\right\}$

27. $y_1 - y = \dfrac{R^3}{\xi\,\theta}\left\{\tau\,(P\sin.\,\alpha + Q\cos.\,\alpha)(\cos.\,\delta + \delta\sin.\,\delta) + P\,\dfrac{\delta + \sin.\,\delta\cos.\,\delta}{2} - Q\,\dfrac{\sin.^2\delta}{2} - A\sin.\,\delta + E\right\}$

Assuming now that the left end of the arch did not change its position, or that equation 26 gives $x_1 - x = 0$ for $\delta = \alpha$, the same equation with $\delta = -\alpha$ must give $x_1 - x = -2\,\lambda\,a$.

The first of these conditions gives us

28. $C = \tau\,(P\sin.\,\alpha + Q\cos.\,\alpha)(\sin.\,\alpha - \alpha\cos.\,\alpha) + P\,\dfrac{\sin.^2\alpha}{2} - Q\,\dfrac{\alpha\sin.\,\alpha\cos.\,\alpha}{2} + A\cos.\,\alpha$;

and by the second we obtain, with the value of C by 28,

29. $-2\,\lambda\,a = \dfrac{R^3}{\xi\,\theta}\,[2\,\tau\,(P\sin.\,\alpha + Q\cos.\,\alpha)(\sin.\,\alpha - \alpha\cos.\,\alpha) - Q\,(\alpha - \sin.\,\alpha\cos.\,\alpha)]$

Equation 27 must give $y_1 - y = 0$ for $\delta = \alpha$, hence

30. $E = -\tau\,(P\sin.\,\alpha + Q\cos.\,\alpha)(\cos.\,\alpha + \alpha\sin.\,\alpha) = P\,\dfrac{\alpha + \sin.\,\alpha\cos.\,\alpha}{2} + Q\,\dfrac{\sin.^2\alpha}{2} + A\sin.\,\alpha.$

Equation 27 must also give $y_1 - y = 0$ for $\delta = -\alpha$, hence with the value of E by 30,

31. $0 = -P(\alpha + \sin.\,\alpha\cos.\,\alpha) + 2A\sin.\,\alpha$

We shall now apply these equations to the different cases I, II, III and IV, considered in investigating the effect of load.

I. ARCH FIRMLY HELD AT BOTH ENDS.

Since equation (25) must give $\delta_1 - \delta = 0$ for $\delta = \alpha$ and for $\delta = -\alpha$, we deduce, by adding the two equations obtained by putting in 25, first $\delta = \alpha$, and then $\delta = -\alpha$,

$$\text{I}h.\quad A = P\cos.\,\alpha\,;$$

and by subtracting one from the other,

$$\text{I}i.\quad \tau\,(\text{P sin.}\alpha+\text{Q cos.}\alpha)=\frac{\text{Q sin.}\alpha}{\alpha}.$$

Substituting for $\tau(\text{P sin.}\alpha+\text{Q cos.}\alpha)$ in 29 its value by Ii, and putting, as on page 487,

$$\text{K}=\alpha+\text{sin.}\alpha\ \text{cos.}\alpha-\frac{2\ \text{sin.}^2\alpha}{\alpha},$$

we obtain

$$\text{I}j.\quad \text{Q}=\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\,\alpha}{\text{K}\,\text{R}^2},$$

By combining equations 31 and Ih., we find

$$\text{I}k.\quad \text{P}=0\,;$$

and

$$\text{I}l.\quad \text{A}=0.$$

The moment of flexure at the abutment will be obtained by Ii.

II. ARCH FIRMLY HELD AT THE LOADED END, AND THE UNLOADED END RESTING ON A PIVOT.

Substituting in equation 23 the values of P_1 and Q_1 by 21 and 22, and putting, as before,

$$\tau=1-\frac{b}{\text{R}}\ \text{and}\ \tau_1=1-\frac{b_1}{\text{R}},$$

we deduce

$$\text{II}l.\quad \tau\,(\text{P sin.}\alpha+\text{Q cos.}\alpha)=\tau_1\,(-\text{P sin.}\,\alpha+\text{Q cos.}\,\alpha)$$

and now as equation 25 must give $\delta_1-\delta=0$ for $\delta=\alpha$,

$$\text{II}m.\quad \text{A}=\tau_1\,\alpha\,(-\text{P sin.}\,\alpha+\text{Q cos.}\alpha)+\text{P cos.}\,\alpha-\text{Q sin.}\,\alpha.$$

With this value of A equation 31 becomes

$$\text{II}n.\quad 0=\text{P}\,t+\text{Q}\,t_1,$$

wherein t and t_1 are the same auxiliaries as employed on page 489 (see equation IId).

From equation 29 we deduce by IIl,

$$\text{II}o.\quad 0=\text{P}\ \delta+\text{Q}\ \delta_1-\frac{2\,\lambda\,a\,\xi\,\theta}{\text{R}^3},$$

δ and δ_1 being the same as by IIg on page 489.

Putting now $\text{K}=t\,\delta_1-t_1\,\delta$ as by IIi., we find from IIn. and IIo.,

$$\text{II}p.\quad \text{P}=-\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\,\alpha}{\text{R}^2}\cdot\frac{t_1}{\text{K}}$$

$$\text{II}q.\quad \text{Q}=\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\alpha}{\text{R}^2}\cdot\frac{t}{\text{K}}$$

The value of b, or the moment at the abutment, can be found by IIe.

III. ARCH FIRMLY HELD AT UNLOADED END, AND THE LOADED END RESTING ON A PIVOT.

Since 25 must give $\delta_1-\delta=0$ for $\delta=-\alpha$, we have

$$\text{III}j.\quad \text{A}=-\tau\,(\text{P sin.}\,\alpha+\text{Q cos.}\alpha)\alpha+\text{P cos.}\alpha+\text{Q sin.}\,\alpha\,,$$

Equation 31 becomes with this value of A

$$\text{III}k.\quad 0+\text{P}\,t+\text{Q}\,t_1$$

wherein t and t_1 have the same values as in IIIc., page 489.

With the auxiliaries δ and δ_1 (see IIIe, page 490) equation 29 may be written

$$\text{III}l.\quad 0=\text{P}\ \delta+\text{Q}\ \delta_1-\frac{2\,\lambda\,a\,\xi\,\theta}{\text{R}^3}$$

And now with $\text{K}=t\,\delta_1-t_1\,\delta$ as by IIIg, (page 490), we find by IIIk and IIIl,

$$\text{III}m.\quad \text{H}=-\frac{1\,\lambda\,\xi\,\theta\ \text{sin.}\alpha}{\text{R}^2}\cdot\frac{t_1}{\text{K}}$$

$$\text{III}n.\quad \text{Q}=\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\,\alpha}{\text{R}^2}\cdot\frac{t}{\text{K}}$$

IV. BOTH ENDS OF THE ARCH PIVOTED, OR b AND b_1 KNOWN.

Substituting for P_1 and Q_1 in 23, their values by 21 and 22, and employing the auxiliaries τ and τ_1 (IVa, page 490) we find

$$\text{IV}g.\quad \text{P sin.}\,\alpha=\text{Q cos.}\,\alpha\ \frac{\tau_1-\tau}{\tau+\tau_1}$$

and now by 29, and employing the auxiliary K (see IVe, page 490),

$$\text{IV}h.\quad \text{Q}=\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\alpha}{\text{K}'\,\text{R}^2}$$

Q being known, we obtain P by IVg, and the constants A, C and E by 31, 28, and 20.

In the particular case IV′, when $b=b_1=0$, we find

$$\text{Q}=\frac{2\,\lambda\,\xi\,\theta\ \text{sin.}\,\alpha}{\text{K}'\,\text{R}^2}$$

(for K′ see IV′e, page 491);

and P=0.

These formulæ consider only the effect of a certain *change* of temperature, hence, to compute the resistances of the abutments for a given *degree* of temperature, we must know what they are for some other degree. For this purpose we assume the arch to be made of such size

that at a medium temperature, say 60°F., it fits exactly between the abutments; in which case the temperature will create no strains at all. Assuming further the extreme of temperature to be 80° F.* above and below this medium temperature, we obtain the extreme values of the resistances of the abutments due to temperature, by employing the following values of the coefficient λ (for wrought iron and steel), viz:

for the greatest heat (140° F.)

$$\lambda = 0.000527$$

for the greatest cold (−20° F.)

$$\lambda = -0,000527$$

APPLICATION OF THE FORMULÆ.

The strains in an arch bridge, if we omit those caused by wind, arise out of three different causes:

1st. The permanent load.
2d. The movable load.
3d. The temperature.

The permanent load may be considered as being uniformly distributed over the whole length of the span, and we find the resistances of the abutments due to the permanent load, viz:

P' and P'_1 = the vertical components,
Q' and Q'_1 = the horizontal components,

$$\left.\begin{array}{l} M'_0 = b' \; (P' \sin. \alpha + Q' \cos. \alpha) \\ \text{and } M'_1 = b'_1 \; (P'_1 \sin. \alpha + Q'_1 \cos. \alpha) \end{array}\right\}$$

the moments of flexure at the abutments, by putting in the formulæ deduced for movable load $\beta = -\alpha$, and substituting for q the quantity q' = the permanent load per unit of horizontal length of the arch.

The resistances of the abutments due to the movable load we denote by P'' and P''_1, Q'' and Q''_1, M''_0 and M''_1, and those due to temperature by P''' and P'''_1, Q''' and Q'''_1, M'''_0 and M'''_1.

The total resistances of the abutments caused by permanent load, movable load, and temperature combined will then be:

$$P = P' + P'' + P'''$$
$$P_1 = P'_1 + P''_1 + P'''_1$$
$$Q = Q' + Q'' + Q'''$$
$$Q_1 = Q'_1 + Q''_1 + Q'''_1$$
$$M_0 = M'_0 + M''_0 + M'''_0$$
$$M_1 = M'_1 + M''_1 + M'''_1$$

If the arch is firmly bolted to the abutments, as in the Illinois and St. Louis Bridge (Fig. 4), the formulæ of

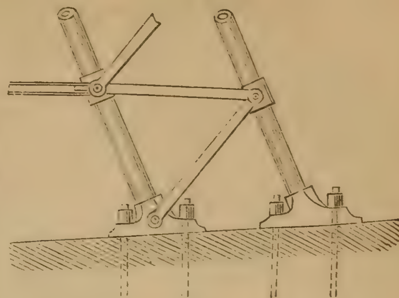


FIG. 4.

case I have to be used; and if the arch rests with each end on a pivot in its center-line (Fig. 5), those of case IV

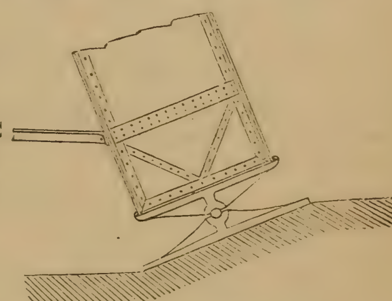


FIG. 5.

will answer for all positions of load and for all degrees of temperature. If, however, each end of the arch is finished with a flat surface (Fig. 6) or with two

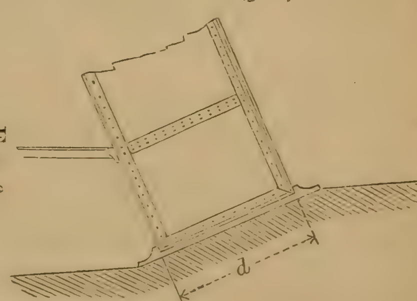


FIG. 6.

pivots (Fig. 7) the bending moment at

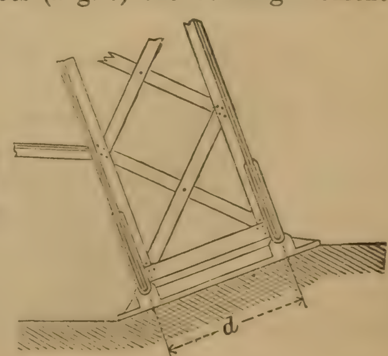
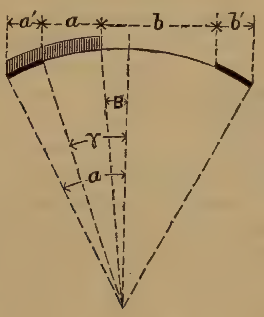


FIG. 7.

* This may appear too much, but we have to make some allowance for inaccuracy of workmanship and also on account of the effect of the compression by the strains in the direction of the arch, as will be shown on page 495.

an abutment may become sufficiently great to lift one edge of the end-face, or one pivot, entirely off the abutment, throwing all the strain on the other edge or pivot. The direction of the tangent to the center-line of the arch, which remained the same as long as the whole end-face or both pivots were in contact with the abutments, is now suddenly changed, and is subject to be changed again by the slightest variation of load or temperature. As this can take place at one abutment only, or at both together, every one of the cases, I, II, III, and IV, may be applicable to the same arch, solely depending upon certain conditions of load and temperature.

In order to find for any particular load or temperature, which case is to be applied, we first compute the total resistances of the abutments by the formulæ of case I, and then compute



$$33 \quad b=\frac{M_0}{P \sin. \alpha + Q \cos. \alpha}$$

$$\text{and } b_1=\frac{M_1}{P_1 \sin. \alpha + Q_1 \cos. \alpha}$$

Case I will be applicable as long as *both* b and b_1 are between the limits $+\frac{d}{2}$ and $-\frac{d}{2}$ (see Figs. 6 and 7, Page 29).

If *one* of the two quantities $\left\{\begin{matrix} b_1 \\ b \end{matrix}\right\}$ is beyond these limits (greater than $+\frac{d}{2}$ or smaller than $-\frac{d}{2}$) we have to compute the resistances of the abutments over again by the formulæ of case $\left\{\begin{matrix} \text{II} \\ \text{III} \end{matrix}\right\}$ putting $\left\{\begin{matrix} b_1 \\ b \end{matrix}\right\} = +\frac{d}{2}$ or $-\frac{d}{2}$, the sign of $\frac{d}{2}$ to agree with that of $\left\{\begin{matrix} b_1 \\ b \end{matrix}\right\}$ computed by 33. With the new values of the resistances of the abutments we compute again $\left\{\begin{matrix} b \\ b_1 \end{matrix}\right\}$ by 33. If we find $\left\{\begin{matrix} b \\ b_1 \end{matrix}\right\}$ still within the limits $+\frac{d}{2}$ and $-\frac{d}{2}$, the formulæ of case $\left\{\begin{matrix} \text{II} \\ \text{III} \end{matrix}\right\}$ are applicable; and if we find it beyond these limits the formulæ of case IV have to be used.

If *both* b and b_1 computed by 33 with the resistances of the abutments obtained by the formulæ of case I, are beyond the limits $+\frac{d}{2}$ and $-\frac{d}{2}$, we have also to try first case II or III, assuming that end of the arch as pivoted for which we had obtained the greater absolute value of b or b_1, and we are only justified in using the formulæ of case IV if the new resistances of the abutments as computed by the formulæ of case II or III, substituted in 33, give for the fixed end of the arch still a value absolutely greater than $\frac{d}{2}$.

INTERIOR FORCES OR STRAINS.

On page 483 we separated the total interior force acting in a normal section of the arch into a moment M, and two forces S′ and S″, the former lying in the direction of a tangent to the central curve of the arch, the latter in the direction of the normal. We distinguish S′ as the *strain in the direction of the arch*, S″ as the *shearing strain.*

The quantities M, S′ and S″ due to permanent load, movable load, and temperature combined, for any point (x, y) of the arch can be computed by the following equations:

a/ for loaded part (from $x=0$ to $x=na$)

$$34a \quad M=M_0-Px+Qy+\frac{q'x^2}{2}+\frac{qx^2}{2}$$

$$35a \quad S'=Q \cos. \delta+(P-q'x-qx) \sin. \delta$$

$$36a \quad S''=Q \sin. \delta-(P-q'x-qx) \cos. \delta$$

b/ for unloaded part (from $x = n\,a$ to $x=2a$)

$$34b \quad M=M_0-P\,x+Q\,y+\frac{q'\,x^2}{2}+q\,n\,a\left(x-\frac{na}{2}\right)$$

35*b* $S' = Q \cos. \delta + (P - q'x - qna) \sin. \delta$

36*b* $S'' = Q \sin. \delta - (P - q'x - qna) \cos. \delta$

As engineers have to deal with moments of flexure and shearing strains in the calculation for every girder or truss I may assume their effect on the different parts of construction (chord and web members) as known, and I will only mention that a positive moment M will create positive or compressive strain in all parts below, and negative or tensile strain in all parts above the neutral axis of the arch.

The strain in the direction of the arch, S', is always positive and, passing through the center of gravity of the cross-section, will create a positive or compressive strain uniformly distributed over the whole sectional area of the arch. This strain has to be added to those caused by the moment M.

EFFECT OF COMPRESSION BY THE STRAINS IN THE DIRECTION OF THE ARCH.

The effect of these strains has been omitted in the calculation of the resistances of the abutments. We shall now investigate the error produced by this omission.

By the strains in the direction of the arch the elements of the arch are compressed in their original direction, and hence the arch is shortened without being deflected. The distance between the abutments, however, remaining unchanged, the effect of this compression is the same as that of such a decrease of temperature as would cause the same shrinkage of the arch.

Putting A = the sectional area of the arch, the compression per unit of cross-section produced by the strain in the direction of the arch is $\frac{S'}{A}$ and the shortening of the element ds of the arch will be $\frac{S'}{A} \cdot \frac{1}{\varepsilon} \cdot ds$.

As for a given load and temperature no great variations will take place in the strains S', we may, with sufficient accuracy, assume an average value of S' and consider it constant throughout the whole arch. We may then compute the resistances of the abutments due to the strains in the direction of the arch, or the amount of the error produced by omitting these strains, by the formulæ deduced for the effect of temperature, using the coefficient

$$\lambda = -\frac{S'}{A \cdot \varepsilon}.$$

If we had always the same condition of load and temperature we could avoid this error entirely, by constructing the arch so much larger than the space between the abutments that the strains in the direction of the arch would compress it to the right size. For our various cases of load and temperature we can at least reduce this error materially by constructing the arch of such size that the strains in the direction of the arch due to the permanent load, and the movable load on one-half of the span, at the medium temperature, will bring it to the right length.* We shall thus have considered an average value of the strains in the direction of the arch, and the errors produced by assuming this average value instead of the true one will be so small that an addition of a few degrees of temperature in computing the strains resulting from this cause, will be found a sufficient allowance for them.

GENERAL REMARKS.

In the preceding pages we have considered only such cases in which the movable load extends from one end of the span, or $x=0$, to a certain point $x = na$. It is, however, clear that our formulæ can also be used to obtain the resistances of the abutments when the movable load does not commence at $x=0$, but extends only from some point $x = n'a$ to some other point $x = na$. We have simply to deduct, in such a case, from the values obtained by our formulæ for a load extending from $x=0$ to $x = na$, those obtained by the same formulæ for a load extending from $x=0$ to $x = n'a$.

For all practical purposes, however, when it is only important to know the maxima of strain which may occur in

* The great accuracy in the construction of the abutments, with regard to their distance and their angle of inclination, which is required for the correctness of the strains, might seem difficult to attain, and even, if attained, may be disturbed again by a slight settling of the abutments. The consequences of such an event, however, would not be serious. Whenever, on account of a slight deviation from the dimensions assumed in the calculation some part of the arch is strained beyond the elastic limit, the permanent set thus caused must necessarily be a step towards restoring the conditions upon which the calculation has been based; hence the arch has a tendency to accommodate itself in course of time to its abutments.

any part of the arch, it will be found sufficient to make the computation for movable loads covering, say, $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$,...... $\frac{7}{8}$ and the whole span, or for $n=\frac{1}{4}$, $\frac{2}{4}$, $\frac{3}{4}$, ...$\frac{7}{4}$ and $n=2$, and for both extremes of temperature.

The strains due to changes of temperature will be found to be by no means insignificant, and it may be worth while to examine them a little closer. To simplify the case, let us suppose the arch to consist of two members or chords, each of the cross-section A, connected by a suitable system of braces. If δ is the distance between the centers of gravity of the sections of the chords, the moment of inertia of the cross-section of the arch will be very approximately

$$\theta=\frac{A\delta^2}{2}$$

The strain by temperature in one chord may then be expressed by

$$T=\frac{S'}{2}\pm\frac{M}{8}=\lambda\,\varepsilon\,\theta\left(f\pm\frac{1}{\delta}\cdot f'\right)=\tfrac{1}{2}\,\lambda\varepsilon A\,(\delta^2 f\pm\delta f')$$

wherein f and f' are certain functions of R, $\propto$, x and y. This shows plainly that the strain from temperature is in direct proportion to the sectional area of the chords, or that for a given span, rise and depth of arch the strain per square inch of section due to temperature is also given. We can see now, at once, the advantage of using steel for arch-bridges instead of wrought iron. Assuming, for instance, the greatest strain from temperature to be 4000 pounds per square inch,* and allowing, as a maximum, 10,000 pounds per square inch on wrought iron and 20,000 pounds per square inch on steel, a wrought-iron arch will lose 40% of its total strength by the strains from temperature, while a steel arch of the same general proportions will lose but 20%; or six pounds of steel will reach as far in supporting a given load as sixteen pounds of wrought iron. In large spans, where the weight of the structure forms a great portion of the total load to be carried, the use of steel will be still more advantageous.

The strains from temperature, or the loss of available strength of the material from this cause, can also be diminished by diminishing the depth δ of the arch. The strength of the arch to resist the strain in its own direction is not altered by changing the value of δ, and it is only its ability to resist the moments of flexure due to unequal loads which is impaired thereby, and to restore which the section A of the chords would have to be increased. The most advantageous value of δ will be best found by experiment, but we can see that the greater the spans, and hence the greater the permanent load compared with the movable load, the smaller may be the depth of the arch compared with the span and the smaller will be the loss of strength by the strains from temperature.

In all our calculation, so far, we have assumed the same cross-section of the arch for the whole span. Economy, however, will in most cases demand various cross-sections for different parts of the arch. For instance, in an arch with fixed ends, as those of the St. Louis Bridge, the chords near the abutments are subject to much greater strains than in other portions of the arch, and should therefore be made stronger. In the calculation for the St. Louis Bridge this strengthening of the ends of the arch has been considered in the following manner. Instead of distinguishing, as we have done, only two different parts of the arch, a *loaded* part and an *unloaded* part, there were four different parts, viz.:

a' a loaded end-piece,
a a loaded middle-piece,
b an unloaded middle-piece,
b' an unloaded end-piece.

Instead of having two equations each of 10, 13 and 14 there were four of each kind, and consequently also 12 constants of integration instead of our six. The six additional equations, which are required for the elimination or determination of these constants, are obtained by the following conditions :

$$\left.\begin{array}{l} 10a' \text{ and } 10a \\ 13a' \text{ and } 13a \\ 14a' \text{ and } 14a \end{array}\right\} \text{must be identical for } \delta=j$$

$$\left.\begin{array}{l} 10b \text{ and } 10b' \\ 13b \text{ and } 13b' \\ 14b \text{ and } 14b' \end{array}\right\} \text{must be identical for } \delta=-j$$

In conclusion, I may remark that all formulæ deduced in the course of this paper may also be applied to a suspended arch by simply changing the sign of q and q', whereby the compressive strains due to load will be changed in tension and *vice versa.*

* We assume the same for steel and wrought iron, as as also λ and ε are about the same for both materials.

SLIDING FRICTION ON AN INCLINED PLANE.

By Prof. A. S. KIMBALL.

From "The American Journal of Science."

The following investigation was undertaken with a desire to demonstrate, if possible, by a laboratory experiment, that the law which affirms that the coefficient of sliding friction is constant for all velocities is not strictly true.

Our results seem to establish the point, at least in the case of bodies sliding down an inclined plane. I am aware that the truth of this law has been questioned; indeed the opinion of very many practical mechanics is directly opposed to it. Long ago Prof. Playfair remarked, as the result of some observations made at the slide of Alpnach, that it would appear that friction is neither proportioned to the pressure nor independent of the velocity. Later observations made at the launching of the Raritan and the Princeton (Jour. Frank. Inst., 3d, VII., 108) showed that the coefficient of friction just before the vessel left the ways was much less than during the first five seconds of its motion. More recent still are the experiments of M. Bochet (Comptes Rendus, April 26, 1858), upon the friction of railway carriages and brakes, which point to the same conclusion; indeed the author goes so far as to give the form of the function which expresses the variation of the coefficient of friction with the velocity, and gives approximate values to its constants for the case of railway trains. His formula is copied by Weisbach with a caution.

Opposed to these views are the careful experiments of Coulomb and Morin, upon which the statements of our textbooks are founded.

The apparatus used in our experiments was simple, but it seems capable of giving very sharp and reliable results. A smooth pine plank $10' \times 12'' \times 2''$ was firmly placed at a measured angle with the horizon and supported throughout by stout beams. Upon this plank was a weight box with pine runners, having a bearing surface of 24 square inches. The cover of the box was about six feet in length, and upon it were placed slips of smoked glass. Firmly fixed above the glass, to an independent support, was a verified tuning fork of 435 complete vibrations per second, carrying a style which lightly touched the glass surface beneath it. The weight box was supported in position at the upper end of the inclined plane by a cord fastened to a screw which served to give the box a very slow upward motion. At the proper time the screw was turned, the fork vibrated, the cord cut or burned off, and the box allowed to slide to the bottom of the plane. The style of the fork at the same time would trace upon the smoked glass a waved line, which would be a perfect autographic register of the experiment. The time of sliding, the velocity at any point, the distance passed over in any unit of time, could all be measured or counted directly from the smoked glass.

The graphical method of working up the experiment was employed as follows: The bottom of a sheet of section paper was made a "time line" ($\frac{1}{435}$ of a sec. = a unit). At various points on this line the corresponding velocities were erected as ordinates. The equation of a line connecting the upper extremities of these ordinates would express the law of the motion studied.

It is evident that this line would have been straight if the acceleration of the slide had been uniform, like that of a body falling in vacuo. If, however, a variable resistance be opposed to the motion of the slide, the acceleration will no longer be uniform, and the line will become curved, concave toward the axis of abscissas, if the resistance is increasing, convex if the resistance diminishes. The acceleration of such a motion at any time will be proportional to the tangent of the angle which the direction of the curve at that point makes with the time line. It is also evident that such acceleration may at once be measured from the paper, since it is the difference between the velocities for two successive units of time. The curve constructed as above, from every experi-

ment made, was decidedly convex toward the time line, showing a constantly decreasing resistance to the motion of the slide as the velocity increased. If we assume that this increase in acceleration was due to a diminished coefficient of friction, the value of the coefficient for any time may be found in the following manner :

Let a, b and h=the altitude, base, and length of the inclined plane.

W=weight of the slide and contents.

W'=normal pressure on the plane, $=W.\frac{b}{h}$.

g=acceleration of a body falling freely.

g'=theoretical acceleration of the slide $=g.\frac{a}{h}$.

g''=the observed acceleration at any time.

Then the resistance of friction $=F=\frac{W}{g}(g'-g'')$, and the coefficient of friction $=\Phi=\frac{F}{W'}=\frac{g'-g''}{g}\cdot\frac{h}{b}=\left(\frac{a}{h}-\frac{g''}{g}\right)\frac{h}{b}=\frac{a}{b}-\frac{g''h}{gb}$=tangent of inclination$-\frac{g''h}{gb}$.

The following tables give the results obtained from a series of four experiments. The load in every case was 40 lbs. The inclinations of the plane were as follows : No. 1=15° 6′, No. 2=16° 9′, No. 3=17° 5′, No. 4=18° 9′.

TABLE A.

Velocities.	Accelerations. Expt. 1.	2.	3.	4.
4	.020	.033	....	...
10	.035	.056	.073	.092
15	.044	.070	.090	.112
20	.053	.081	.103	.129
25	.059	.083	.112	.140
30	.065	.094	.120	.150
40	.073	.105	.131	.165
50	.078	.112	.140	.176
60	.083	.117	.148	.184
70	.087	.121	.156	.190
80	.091	.125	.159	.196
90	.093	.128	.163	.200
100	.095	.131	.168	.203
110	....	.133	.171	.206
120	....	.136	.175	....

Table A shows the accelerations corresponding to different velocities in the four experiments. The units used are the $\frac{1}{1000}$ of an inch and the $\frac{1}{435}$ of a second.

Table B shows the coefficients of friction in each experiment, deduced by substituting the observed accelerations given in Table A in the formula given above. The observed accelerations were of course reduced to feet in a second.

TABLE B.

Velocities.	Coefficients of friction. Expt. 1.	2.	3.	4.
4	.260	.273	....	....
10	.252	.261	.270	.280
15	.245	.254	.261	.270
20	.243	.248	.254	.260
25	.240	.245	.250	.255
30	.237	.242	.246	.250
40	.233	.236	.240	.242
50	.230	.232	.235	.236
60	.228	.230	.231	.232
70	.226	.228	.227	.231
80	.224	.226	.226	.225
90	.223	.224	.224	.223
100	.222	.223	.221	.222
110	....	.222	.220	.220
120	....	.220	.217	....

From the tables it will be observed : 1st. That with a given inclination of the plane, the coefficient of friction decreases as the velocity increases, rapidly at first but more slowly afterward. 2d. With the same velocity, the coefficient of friction is greater the greater the inclination of the plane, within the limits of the experiments. 3d. The coefficient of friction in each experiment tends toward a constant quantity. 4th. This constant seems to be the same in each experiment.

No simple expression which will show the variations in the coefficient of friction has yet been found ; indeed, I have not thought best to attempt to formulate the work till certain errors which will be referred to, have been corrected. It was found impossible to procure a plank with a perfectly uniform surface. The one used in the experiments given showed at the same inclination and velocity a coefficient which slightly but regularly increased from one end to the other. The end which gave the lower coefficient was placed uppermost. The obvious result of this was to make the coefficients in Table B at high velocities greater than they otherwise would have been. This fact also explains the apparent anomaly in columns 3 and 4 of the same table,

where the coefficients at high velocities are seen to fall below the corresponding coefficients in column 2.

In experiment 4 the slide had the velocity 120 at a distance of 40 inches from the upper end of the plane ; in experiment 2 it did not acquire that velocity until it had passed over a distance of 60 inches, and consequently was on a rougher portion of the plane. The uniformity of the plane was tested by starting the slide at different points along its length, and comparing the curves on the smoked glass. These experiments have not been corrected for the resistance of the atmosphere. The effect of such a correction would be to diminish still more the coefficients at high velocities.

As the inclination of the plane increases the normal pressure decreases. Thinking that this change of pressure might explain a part of the difference due to a change of inclinations, we made three experiments at the same inclination, with weights of 18, 80 and 140 lbs. in the box. At the end of one second we found the velocities in the three cases to be as 1, 1.18 and 1.32, showing a less resistance in the case of the greater load, and corresponding to a decrease of about 2¼ per cent. in the coefficient of friction. This seems to be insufficient to explain the change in the coefficient when the inclination of the plane is changed. But it is interesting as showing that in the case of pine on pine friction is not strictly proportional to the normal pressure.

As soon as possible we propose to repeat these experiments, extending the range of velocities, also to try the effect of a change of pressure, with a view to formulate deviations from the received laws, if simple expressions can be found. We have also designed a modification of apparatus to test our results when a uniform motion is given to the slide.

BANNER'S SYSTEM OF SANITATION.

By Major H. C. SEDDON, R. E.

From "The Architect."

For the past few years there have been great advances towards remedying the evils to which the convenience of having water-closets inside our dwellings has chiefly given rise. Many have been the patents taken out for closets trapped in diverse ways, as well as for sewer traps, till at one time freedom from sewer gas was generally supposed to be in direct proportion to the number and ingenuity of the traps intervening between the sewer and its different connections with the interior of the house. Then, however, the dreadful truth was announced that sewer gas, under pressure, could, nay did, force its way through all water traps, and that the suction caused by the passage of sewage matter through the pipes frequently unsealed the best traps by drawing the water out of them. Gradually, and only very gradually, has the device been adopted of providing safety-valves, to take undue pressure off the traps by leaving the soil-pipes open at the top. It would, perhaps, not be far wide of the mark to assert that in the larger number of houses erected every year even this simple precaution is omitted ; whilst generally, where it is done, a small pipe carried up to the roof of the house, for the sake of a paltry saving, is made to do duty for the whole section of the soil-pipe. Now, however, an entirely new method of dealing with our soil-pipes is being prominently brought before the notice of the public. This is known as the "Banner System," after the gentleman who originated it in his own defence, and who worked out the details which form such important features in its practical application. Mr. Banner tells us that immunity from sewer gas is not to be obtained by a multitude of traps, but rather by having but one trap. At one fell swoop he does away with all the traps upon which we have hitherto relied for safety. By means of a very ingenious trap of his own invention, fixed at the foot of the soil-pipe, he cuts off

effectually all communication between the soil-pipe and the drain below. This done, he induces a constant current of fresh air from the bottom to the top of the soil-pipe, by means of a patented wind-cowl fixed at the top of the soil-pipe, above the roof of the house.

Mr. Banner's house is situated on high ground, at a level of about 150 feet above the sea. It has a good external appearance, but, being on a terrace, is only open to the air at the back and front. At the back the ground is open, without anything to impede the view. The reception rooms are large, lofty, and well lighted, and the bedrooms are of good size and height; in all there are seventeen rooms, besides the kitchen offices in the basement. The above is all that can be said in favor of the house, for, in my opinion, one worse constructed, so far as all accepted theories of sanitary arrangements are concerned, it would be difficult to find. The water-closets are placed in the very worst positions that could be selected. After passing through the entrance hall, you come upon the inner hall, with a well staircase lighted by a skylight near the roof. Off this hall is a water-closet, with another immediately above it on the second floor, both being in the centre of the house and next to the party wall of the adjoining house, where no fresh air or other than borrowed light can reach them; and, as if to make the conditions still worse, both closets, which are only 4 feet by 3 feet, are reached by passing through closely-confined lobbies, 3 feet by 3 feet, that on the ground floor being fitted up with a lavatory basin, and on the second floor with a small housemaid's sink, and each containing a gas burner, which in winter has to be lighted at 5 P.M., causing the temperature in these unventilated boxes to range at the ceiling line from 80° to 90°, and even higher, although the thermometer outside may be below freezing point. Common pan closets, with the ordinary receivers, or storage chambers for filth, formerly discharged their contents through leaden D traps into a solid pipe trapped below and closed above, whilst the drain leading from the soil-pipe ran, as it still does, under the kitchen floor in the basement to the sewer in the middle of the road, with a very quick fall; receiving on its way, besides part of the roof water, a tributary drain from the scullery sink as well as the contents of the servants' closet, which is under the street pavement, and opening off the front area. Situated as the house is, nearly at the highest point of a branch sewer, with no ventilating pipe carried up above the roof to relieve the house traps from the pressure of sewer gas, it is not much to be wondered at that the nuisance arising from his well drained house nearly drove Mr. Banner to despair, until at last it became a question of either finding some means of remedying the evil, or of seeking refuge in flight. Mr. Banner, however, proved equal to the emergency, and although at that time ignorant of the very A B C of house drainage, determined to prove the truth of the old proverb that "necessity is the mother of invention." He set to work seriously, mastered the details connected with his own troubles, first carried up the open soil-pipe above the roof of the house, and after many trials eventually succeeded, and I say so on conviction, in constructing a trap which most effectually cuts off all chance of sewer gas finding its way into any part of the soil-pipes within the house. There was a great point gained, and seems naturally to have led up to the next step, which, as I shall explain further on, appears to me to be the most important point in the whole system, namely the outlet to the open air just above the patent trap at the foot of the soil-pipe. This became a necessity, owing to the air driven down the soil-pipe by water descending from the closets above not being able to force the patent trap as it would an ordinary syphon trap, the result being, that it had to escape through the closet pans, and other trapped passages, into the house. This apparent objection to the rigid barrier placed at the foot of the soil-pipe, no doubt suggested the idea of providing a free outlet below for the air forced down by the sewage matter in its descent. The soil-pipe running down the centre of the house being now open to the air both at top and bottom, and effectually cut off from the sewer, the crowning point of Mr. Banner's system was attained by placing a patent wind-cowl on the top. The cowl is so constructed that the wind passing through

it produces a constant draught up the soil-pipe, drawing fresh air from the garden level below, and through any untrapped inlets in the house, and so setting up a continuous counter-current in opposition to any tendency of the fires, &c., in the house to draw supplies of air through the house connections with the soil-pipe. The extracting power of the wind-cowl being once established, it became evident that the traps to the closets, sink, bath and lavatory basin were no longer of any use, and therefore, being mere obstructions and receptacles for sewage matter, were removed, leaving nothing but the patent trap at the foot of the soil-pipe to guard the way from the interior of the house and the sewer, except, of course, the water in the pans of the closets when not in the act of discharging.

Mr. Banner's patent trap, the working of which has already been described in these columns, occupies about the same space as an ordinary gas meter, and is concealed from sight by a wood casing in a recess in a cupboard, being fixed about 3 feet above the basement floor. About 6 feet above the trap are the closet and lavatory basin on the ground-floor, about 30 feet higher are the upper closet and housemaid's sink, the bath being some 8 feet higher still, and the wastes from the bath and sink passing into the soil-pipe just below the closet on the second-floor, whilst that from the lavatory basin, on the ground-floor, discharges into the soil-pipe just below the lower closet. The top of the soil-pipe upon which the extracting cowl is fixed, rises about 8 feet above the roof, and, being at the centre of the house, is not visible from the road. The communication with the outer air at the foot of the soil-pipe is formed by carrying a 2-inch pipe just above the trap, under the dining-room floor, to the garden in rear of the house. The cistern, which is above the skylight over the central staircase, supplies the water required for purposes of ablution as well as for the closets. The waste from the cistern discharges on to the lead flat round the skylight, whilst all the water running off the flat passes beneath the floor-boards of one of the top rooms into a down-pipe on the front of the house, discharging over a Dean's patent trap in the area of the basement. Here the waste from the scullery sink, and the rain-water pipe from the roof, are made to discharge in the same way over a similar trap; though why the water from the lead flat should not be turned into the soil-pipe, which is close at hand, and so be made to assist in cleansing it, instead of being carried through the floor of a room, is by no means clear. From the foot of the soil-pipe, which, it is seen, receives none of the refuse water from the kitchen, the drain runs, as already stated, under the kitchen floor and through the area, with a very considerable fall, till it joins the main sewer in the middle of the road, the total distance being about 45 feet; only receiving on its way what passes through the surface traps in the open area, and the contents of the servant's closet under the street pavement, and discharging freely into the sewer without any intervening trap or flap-valve.

Having said thus much about the sanitary arrangements of the house, I have only to add, before passing on to the result of my investigations into the practical working of the system, that no attempt whatever has been made to ventilate any of the rooms, by providing inlets for fresh air or outlets for foul air. Doors and windows do duty for the first, and the smoke-flues for the last. I consider, therefore, that if under no circumstances air has been drawn from the soil-pipe, through the untrapped openings, into the house, the extracting cowl can claim to have performed its duty thoroughly, though placed under the most adverse circumstances.

I will now describe what I saw of the practical working of the system in Mr. Banner's house, and the tests to which it was put in my presence. Beginning at the highest point, namely, the patent cowl—which Mr. Banner informed me had been fixed for over a year, without once getting out of order—I first satisfied myself that it was performing its duty properly, veering with the wind, and drawing up air through the soil-pipe; this was evident from the strong current of air passing in through the mouth of the air pipe running from the garden to the foot of the soil-pipe, as well as from a perceptible indraught through the untrapped pipes from the lavatory basin

and the closets. It was plain, moreover, that no air could be passing from the soil-pipe into the house, though certainly the general conditions of the atmosphere were favorable to the cowl, there being a fair breeze blowing and the temperature being high for the time of the year, so that the drawing power of the house fires was by no means great. As a matter of course it followed that no smell could be perceived arising from either the waste-pipes to the bath, sink, or lavatory basin, or from the closets, even when the handles were purposely kept up, although they were of the common pan description, with the usual receiver, which can never be otherwise than coated with filth inside. Passing down to the bottom of the soil-pipe, we next watched, through the glass plate which forms the front of the patent trap, the action of the cup valve within, while copious discharges were sent down the closets above. By means of a strip of glass inserted in the front of the soil-pipe, just above the top of the trap, the water could be seen rising in the foot of the soil-pipe, until it reached a height of about 12 inches, when the weight of the column of water being sufficient to overcome the resistance of the weight at the end of the lever arm, forced the valve down, discharging the contents of the pipe above into the drain below without unsealing the cup, which, directly the discharge ceased, leaving only the water retained in it when at its lowest point, closed up again, with a slight deadened sound, against the indiarubber ring on the end of the soil pipe; the sound of the trap closing after each discharge was easily detected, even in the upper closet, by anyone listening for the sign of its having done its duty. The air-tight joint upon which the weighted lever was fulcrumed was simply and carefully constructed, and can safely be relied on to prevent the passage of sewer gas. The patent trap itself formed a perfect barrier against the passage of sewer gas from the drain into the soil-pipe above, and could not by any possibility be deprived by suction of the water which alone, when it is open, guards the way; whilst if, from disuse, while the family is away, the water all evaporated, the trap would, I believe, be still a perfect barrier, and could not be opened, except by water discharged from above, which, in the act of opening the cup, would reseal it. That there is no tendency for the sewer gas below the trap to force its way through the water, which seals it when open, in order to exchange places with the sewage matter discharged from the soil-pipe, is due to there being a free passage for sewage matter and sewer gas from below the trap right away to the street gratings; as well as to the freedom with which air enters the soil-pipe above the trap, and replaces the discharged matter, without any effort to restore the equilibrium being required, as is the case with a soil-pipe carefully trapped at every point.

In order to test the efficiency of the trap under extraordinary circumstances, we passed down from the closet above some corks, hair, and a piece of an old curtain about the size of an ordinary duster. The piece of white curtain was seen to pass straight through the trap, which however did not close after it, though, of course, the water seal was maintained. Hot water was then discharged from the upper closet, whilst I stood by the outlet pipe in the garden, from which the air in the soil-pipe rushed with considerable force, but without any disagreeable odor, that I could possibly detect, though I fancied I perceived a very faint smell with the first rush which certainly would have been expected after treating with warm water the inside of a soil-pipe which had been more than twenty years in position, and which must necessarily be fouled by every discharge from a closet; though, of course, it was hardly in its natural condition, after having been washed by so much clean water as had been sent down it in the course of our experiments. The inside of the pipe, I was informed by Mr. Banner, had been found, wherever examined, to be coated to a depth of more than a quarter of an inch with a calcareous deposit not of the sweetest description, to judge from the section of a leaden D trap in a similar condition, which, though it had been removed from its place for more than a year, and left exposed to the air, still emitted a most offensive odor. In order that we might examine into the state of the cup valve and the india-rubber ring against which

it closes, the glass front to the trap was then removed, and the inlet leading from the bottom of the trap to the drain stopped with a conical india-rubber plug kept for the purpose, but not before it was unpleasantly evident that there was sewer gas in abundance ready to force its way through any defective joint, could it but find one out. The cause of the cup refusing to rise was found to be that one of the corks thrown down had been nipped, end on, between the bottom edge of the soil-pipe and the bottom of the cup, just as the latter was in the act of closing, and that the subsequent discharges of water from the upper closet had failed to release it, was owing, without doubt, to the force of the descent being broken by a bend purposely made in the soil-pipe, a little above the trap; the result being that it shot quietly through the open cup, without having impetus enough to lower it, and so to open the jaws which gripped the cork. Had it been so desired, the obstruction might easily have been got rid of, without opening up the trap, by lifting the weighted arm of the lever at the same time that the trap was being flushed from above, but that was not the object we had in view. Such a *contretemps*, I was told, was never known to have occurred before, since the trap was fixed in September 1873, nor do I attach much importance to it, seeing that it would in no way interfere with the proper working of the system, even if the cup remained down for some time before attention was drawn to it, whilst it could be set right in a few minutes without any inconvenience to the inmates of the house. The cup itself was in perfect order, and free from any solid matter (the cork excepted) beyond a slimy coating of lime, which the water deposits on all surfaces with which it comes in contact; whilst the india-rubber ring appeared to be as sound as when first put on, more than a year ago, owing, no doubt, to its constant immersion in water free from destructive agents, such as grease.

When the front of the trap had been replaced, I poured some strong scent into the mouth of the air-pipe leading from the garden to the soil-pipe, in order to ascertain whether the air passing into the soil-pipe might not, at intervals of unequal action, find its way into the house, as well as out through the wind cowl. I was unable, however, to detect the odor of the scent in any part of the house, and must therefore conclude that the suction of the wind cowl was at all times sufficient to overpower that of the house.

The result of stopping up the mouth of the air-pipe leading from the garden was shown by discharging water from the pan of the upper closet, the effect on the lower closet being that the air in the soil-pipe—finding it impossible to force the patent trap below—in its efforts to escape, first raised the level of the water in the pan, and finally burst through, sending the water flying in all directions.

The same operation was then repeated, only with the lever of the patent trap raised, so as to put it in the condition of an ordinary water-sealed syphon; the result was that the air forced the trap without repeating the commotion in the pan of the lower closet. Finally, leaving unstopped the mouth of the air-pipe, and removing the plug of the lavatory basin on the ground-floor, water was again discharged through the upper closet, in order to see whether, under such circumstances, air could be forced into the house through the waste-pipe from the basin. Such however, was not the case, but there was rather a suction through the waste into the soil-pipe. It should be further observed that, so long as the soil-pipe was open to the air at both ends, no amount of water discharged down it had any tendency to draw the water contained in either of the closet pans. I also ought to mention that Mr. Banner had just had a small louvred ventilator placed near the ceiling in the lower closet, in connection with a pipe branching out of the soil-pipe, for the purpose of drawing off the hot air from the ceiling level when the gas is burning. That the extracting power of the wind cowl could, within certain limits, be safely utilized for such purposes there is no doubt, but time had not allowed of any observations being made as to its efficiency.

This closes the account of my investigations into the practical working of Mr. Banner's system of sanitation, as far as I found it had been carried out in his

own house. I have no hesitation in saying that it worked admirably, and that he has succeeded in rendering his house absolutely secure against that most insidious of enemies, "sewer gas," provided no leakage is possible from the drain which passes under the basement floor to his patent trap.

Having already described at considerable length the successful application of Mr. Banner's system to the drainage of his own house, I propose now to examine into its claims to supersede, in whole or in part, other improved methods of treating the pipes which convey sewage matter from our dwellings. In doing this, I shall confine myself in the first instance to soil-pipes and drains, under similar conditions to those against which Mr. Banner had to contend, then pass on to the consideration of buildings designed on principles more in accordance with the requirements of the leading sanitary authorities of the present day, after which I shall have a few words to say with reference to the application of Mr. Banner's patent cowls to the purposes of ventilation in general.

First, then, let us take any house in which the closets are so located within the building that the natural inference is that they are more or less certain to prove sources of annoyance, and consequently elements of danger to the health of the occupants. In such cases I have no hesitation in saying that, if the soil-pipes are treated in the same way as in Mr. Banner's own house, all chance of annoyance from sewage gas would be cut off, provided the drain from the foot of the soil-pipe to some little distance beyond the walls of the house is rendered secure against leakage. This might be accomplished either by the pipe being well cased in Portland cement concrete rendered on the outside with half cement and half sand, or by being formed entirely of Portland cement concrete troweled perfectly smooth on the inside and rendered on the outside, so as to be in one continuous length. Such a drain should be made somewhat of the section of an ordinary oval sewer in miniature, the invert being formed first, and worked quite smooth before being covered in at the top. It is very important to continue the special mode of construction adopted for some distance beyond the walls of the house. Gas escaping from a drain-pipe has a tendency to creep along the outside of the pipe, through the slight voids frequently formed by the shrinking of the soil away from the pipe. It thus can find its way within the walls of the building, and thence ascends to the upper stories through such channels as are afforded by wooden casings to gas, water, soil, or rain water pipes, void spaces behind the lath and plaster on battened walls, &c.; and when it reaches the different floor levels it finds a free passage through the spaces between the floor joists to any rooms that happen to require supplies of air to make good what is being continually consumed and carried up the chimneys by the draught of the fires. However, in order to prevent any annoyance from a closet, it is not sufficient to ventilate the soil-pipe and exclude the sewer gas from it. The proper ventilation of the closet itself is also a necessity; not merely for the purpose of carrying off the heat and fumes arising from gas burners, but also to keep the smell given off from the closet basin, before its contents are discharged, from being perceived in the house. In order to effect this, a small shaft carried up from the closets to the roof of the house, with one of Mr. Banner's patent cowls at the top, would be of the greatest advantage. It would insure a constant up-draught, which can never be depended upon, under all conditions of the atmosphere, unless there is some constant active force at work, such as the cowl would supply, or such as can be obtained by taking advantage of a heat generated in a kitchen flue, supposing one to be available for the purpose.

As the Banner system thus offers a safe way of escape from the evils which are so generally the result of placing closets in the centre of a house, it follows that, where the system is adopted, architects will be, to a certain extent, relieved from the necessity, which has hitherto been felt, of sacrificing the most convenient positions for the closets for the sake of cutting them off from too intimate a connection with the interior of the house. But, while we acknowledge the efficiency of the system as placed before us, we are bound to ask ourselves whether it is at present found in its best

and simplest form for general adoption; whether, in fact, all the details connected with its first introduction to our notice are essential to the success of the principles involved. It is one thing for all the parts to go on smoothly in the hands of those who understand and take an interest in such appliances, whereas it is quite a different matter when we keep in view the ordinary householder's indifference, and ignorance of sanitary matters, and the tricks which children and servants contrive to play upon everything within their reach. What would be admirably adapted for the mansions of the wealthy, public buildings, important offices with responsible care-takers, and the homes of those who live in houses of their own, would not be suitable for houses of an inferior description, or for those which are perpetually passing through the hands of tenants. In order, therefore, to enable us to arrive at some definite conclusions on the subject, I propose to consider the following points, which appear naturally to present themselves for discussion.

1. If we admit that the extracting cowl will act efficiently at all times and under all circumstances, does it not follow that the trap at the foot of the soil-pipe might be removed altogether, and the latter left fully open to assist in ventilating the sewer, in addition to the other duties it is called upon to perform? This is a point which has been put forward more than once, and one which, at first sight, seems only answerable in the affirmative. If the cowl at all times and under all circumstances draws air up the soil-pipe with such force that no air or gas can escape out of the latter, except through the cowl, there does not seem to be any reason why we should place a trap between it and the sewer. Why not let the soil-pipe act as a natural outlet for sewer gas? The only answer I have heard given to this question is, "Well, no doubt you might safely dispense with the trap at the foot of the soil-pipe, but it is not pleasant to know that gas from the public sewer is passing up a pipe within the walls of your house. If the same plan was pursued in every house, well and good, but one does not like ventilating the sewers for the whole community." Such an answer, however, will not bear investigation; for, if a principle is correct, no amount of sentiment ought to stand in the way of its being carried into practice. I think, however, there are sounder reasons for maintaining the separation between the soil-pipe and the sewer. One is that, though the cowl may always be efficient, the pipe below it may, perchance, get stopped up, and so allow the sewer gas to accumulate below the point of stoppage, and thence to force its way, or be drawn into the house, through traps or defective joints, and such a contingency must be guarded against at any cost. Another, and a yet more important reason, is that if the soil-pipe is used to ventilate the sewer, the lower end of it must not communicate with the outer air, and if this point is given up, all the benefit to be derived from Mr. Banner's system is given up with it, leaving us still liable, at each discharge of a closet, to have sewer gas forced into our dwellings. It is therefore clear that a trap at the foot of the soil-pipe is necessary, and ought not to be dispensed with; whilst, if the sewers are to be ventilated, a special pipe should be used for that purpose, which should be kept outside the house, and not be allowed to pass through it, for several reasons which need not be gone into here.

2. Taking it, therefore, as an admitted fact that the soil-pipe must be cut off from the drain into which it discharges, and allowing, for the sake of argument, that Mr. Banner's lever trap is to be the one used (the term "*lever* trap" is used to distinguish it from Mr. Banner's last patent, which is "double dip trap"), the next question which arises is, "Would it not be advisable to have some sort of trap close to each closet pan, or other inlet, for the purpose of arresting such articles as brushes, sticks, stones, and the various matters which any plumber will tell you are constantly causing the stoppage of traps and soil-pipes, and necessitating the aid of his valuable services?" This question I think Mr. Banner himself would answer in the affirmative, in the interest of his own trap, as any solid matter finding its way into the bottom of the copper cup would weigh it down, before the water could rise to the ordinary height within the pipe above. The result would be that the descending water would shoot through the

open trap with much less force than usual, and would not, therefore, have a fair chance of dislodging any weighty matter in the bottom of the cup ; and this would effectually prevent it from closing, if such extra weight in the cup caused a preponderance in excess of that due to the weighted arm of the lever, which is so balanced that it only just retains sufficient righting force when the cup contains nothing but its complement of water. That such articles would frequently find their way into the lever trap, if fixed in ordinary houses, cannot be a question admitting of any doubt ; and, when it did happen, the glory of the trap would depart from it, for it would be reduced to the condition of a common dip trap, sealed with, perhaps, not more than half an inch of water. It is true the defect could be remedied with ease in a few minutes, but who would be likely to observe it, for no stoppage would proclaim the fact that anything was out of order; and to suppose that any one in an ordinary house could be relied upon to keep up a series of observations on the height of the lever arm, in order to see whether the cup closed properly, is entirely out of the question. I am afraid that if once the cup got fixed open, it would, as a rule, remain so from one year's end to another. It seems, therefore, clear to my mind that, in order to put any such contingency out of the question, an ordinary syphon trap (certainly not any such abomination as a D trap), is required, wherever the patent lever trap is used, to act as a catch-pit beneath each closet pan, and that all wastes leading into the soil-pipe should be fitted with gratings to prevent the passage of solid matter.

3. This decision brings us to the next point, viz.—If, with a patent lever trap at the foot of the soil-pipe, we ought still to fix traps to the closet basins, the argument that the extra cost of the one trap is in a great measure met by all other traps being dispensed with, falls to the ground ; and we are naturally led to ask ourselves whether a properly constructed syphon trap would not be just as efficient as the patent lever trap. In my opinion it would, and Mr. Banner has practically answered this question in the affirmative, having just patented what may be termed a "double dip, ventilated trap," to be used by those who, like myself, would prefer it to the automatic action of the more costly lever trap. This last trap of Mr. Banner's invention has, I understand, given great satisfaction in his brother's house, and it has the same advantage as his first patent in allowing the working of the traps to be seen through glass plates fixed in its movable face. The outlet from this trap for the ventilating pipe to be carried above the roof of the house, however, appears to me to be unnecessarily large. As the ventilating pipe will in most cases have to be carried up through the house itself, I should have made it much smaller, treating it merely as a safety valve, to prevent any suction unsealing the dip traps ; for the ventilation of the drain itself I should much prefer carrying up an independent pipe, outside the walls of the house. The benefit to be derived from the two dip traps, one immediately below the other, is also I think more than doubtful ; whilst the fall into them is, to my mind, too direct, and the chances of stoppage thereby increased. For my own part I should be perfectly satisfied pith a common 6-inch syphon trap constructed with a gentle sweep into it from the 4-inch soil-pipe, to enable the sewage matter to shoot the trap, instead of falling dead on the surface of the water within it, and provided with an inspection hole placed near the highest point of the trap, instead of at the bottom of the bend, where it helps to arrest everything passing through the trap. Such a trap does not require any safety valve to prevent its being unsyphoned, for the simple reason that the 4-inch soil-pipe can never make the long leg of the 6-inch syphon run full; nor could Mr. Banner's trap be unsyphoned, even if he omitted the ventilating pipe altogether, provided he took care that the outlet from his trap was considerably larger than the inlet to it. With either of these traps there would be no necessity for the catch traps below the closet basins, which could therefore be omitted, as their only object was to prevent the lever trap from being reduced to the condition of a mere dip trap ; thus, the simpler the means we employ, the fewer parts we seem to require, and this without in any way affecting the efficiency of the whole system.

4. The last point to which I shall refer in connection with Mr. Banner's treatment of soil-pipes from closets placed in the centre of a building, is the following —granted that his extracting cowl is very perfect, powerful, and constant in its action, and that when used on the top of a soil-pipe, ventilated at top and bottom, and trapped with a syphon at its point of junction with the drain, all other traps may be dispensed with; taking all this as proved, cannot we carry out the system without the aid of the cowl? My answer to this would be, "certainly, provided you choose to trap the wastes from your sinks, baths, and lavatory basins, and use valve closets of good construction, in place of those receptacles of filth which go by the name of pan closets;" at the same time, I know that Mr. Banner considers that it would not be safe to have the inlet at the bottom of the soil-pipe, without an extracting cowl at the top. In my opinion, by simply allowing the soil-pipe free communication with the outer air, both at the top and bottom, it will be thoroughly ventilated, whilst the traps to the waste-pipes, and the water in the basins of the valve closets, will sufficiently guard against any chance of the suction of the house, even if the rooms are entirely unprovided with proper inlets for fresh air, drawing air from the soil-pipe, provided the pipe is sound, and the joints tight. True, you will not have the suction of the cowl to remedy any tendency for the air in the soil-pipe to enter the house, in the event of the soil-pipe being in any way defective; but, with ordinary care, I do not think there would be sufficient reason for our fixing extracting cowls to all soil-pipes, with the object of guarding against so remote a contingency; though, in large mansions, and other important buildings, such extra precautions might be taken with advantage. That the air in the soil-pipe would be constantly renewed, and, in fact, in a constant state of motion, without the aid of the extracting cowl, must, I think, be evident to all. It is clear that every discharge from a closet would drive out at the foot of the soil-pipe all the air below the level of that closet, and that fresh air would follow in the wake of the descending water; the air in the branch pipe, leading to the soil-pipe, being replaced by air following it through the closet valve—no trap being placed between the valve and the soil-pipe—and the air in the soil-pipe being replaced by fresh air descending through the open top. Moreover, the different conditions of temperature above, below, and within the soil-pipe, arising from various causes, such as the sun warming the top of the pipe above the roof, and the warmth of the house affecting portions of the pipe running through it, would tend to keep up a constant movement of the air within it.

I will now pass on to consider a more favorable condition of affairs, such as would occur in designing a new building, where there are no special circumstances to compel the architects to place the closets in other than what is acknowledged to be the best position for them, namely, against an outer wall, where light and ventilation are at full command. In such a case it is always desirable to enter the closet through a freely-ventilated lobby, with cross ventilation where practicable, and so arranged that under no circumstances can the inlets and outlets be entirely closed. The soil-pipe from the closet should be carried down outside the walls, and, therefore, the junction with the drain being outside the house, no danger can arise from sewer gas finding its way inside the dwelling, except through the branch pipes from the soil-pipe, and this cannot occur if a properly constructed syphon trap is placed at the foot of the soil-pipe; more especially if means are taken to prevent any pressure of gas on the sewer side of the syphon, by carrying up a pipe therefrom to ventilate the drain. Mr. Banner's traps would, it is evident, under such conditions be quite superfluous, as special receptacles would have to be constructed for them outside the building—though, in some cases, I am aware this has been done; whilst, as already pointed out, with the soil pipe open both above and below, quite sufficient ventilation would be obtained without the use of the extracting cowl, which, in any prominent position, would certainly not add to the appearance of the building, From the closets themselves it would be a great advantage to lead up an extracting shaft, surmounted by a patent cowl, in order to remove at

once any unpleasant odor arising from the basins, before the contents are discharged into the soil-pipe.

It will be gathered from what I have already said that, although I look upon any house, treated as Mr. Banner has treated his own house, as perfectly secure against all danger arising from the unhealthy emanations of sewers and their necessary adjuncts, I do not consider the patent trap or the patent cowl essential parts of his system, but that its great claim to attention lies in the thorough ventilation of the soil-pipe, by letting the outer air pass freely in and out at the bottom as well as at the top. This point admitted, I hold that it will be well to dispense, as much as possible, with all contrivances depending on the free motion of working parts, and which involve the wear and tear of mechanically-made joints. That this can be done without running any risk of allowing foul air or gas to pass from the soil-pipes into our houses, I think I have sufficiently demonstrated. If properly constructed valve closets are used, there will be no necessity for any trap between the valve and the soil-pipe. The way should be perfectly clear, and each discharge will then suck air down after it, none will come up through the valve; whereas, where a trap is used, the air between the trap and the valve must make room for the contents of the basin, which it does in the readiest way, namely, by exchanges places with the latter, and so causing that offensive puff of foul air, which is always the result of pulling up the handle of an ordinary closet.

The wastes from baths, basins, and housemaid's sinks should, as at present, be trapped; those from scullery sinks should discharge, if possible, over a trap in the open air, and such trap should be readily cleaned out. Dean's patent trap, which has an iron bucket inside, is about the simplest and best I know of, as the bucket can be raised, emptied, rinsed out, and replaced with the greatest ease, and without hardly soiling the fingers. The safety-pipe carried up from the trap at the foot of the soil-pipe to the top of the house should never be omitted, unless there is some outlet to the open air—such as through a gully grating, not far distant from the trap.

The last remarks I have to make are on the proposed application of Mr. Banner's patent cowls for the thorough ventilation of houses and sewers, in addition to the soil-pipes, as set forth in his pamphlet entitled "Wholesome Houses." As the suggestions of the patentee have not as yet been put to a practical test, there are no ascertained facts to refer to, but I should strongly recommend the three up-cast pipes for extracting the contents of the rooms, the sewer and the soil-pipe, not being united together and submitted to the action of a single cowl; as nothing is accurately known with regard to the amount of work such cowls are capable of performing under different conditions of wind force. It would be much safer to use a separate cowl for extracting foul air from the rooms, whilst in the rooms themselves proper provision should be made for supplying fresh air in place of that carried up the smoke flue and drawn off by the cowl, otherwise the stronger of the two will draw air down the other, and smoky chimneys may have to be cured by removing the cowl from the summit of the foul air pipe; or, if both smoke flue and cowl managed to draw air out of the room, the draughts of cold air from the doors and windows would bring discredit upon ventilation, and make people sigh for the days when every one lived in comfortable ignorance of the reason why their sojourn on earth fell so far short of the 969 years of Methuselah. The advantage of the inlet for fresh air, at the bottom of the pipe for extracting foul air from the rooms, is by no means clear, since this pipe does not require to be kept fresh by a constant current of pure air passing through it; and I take it to be quite a mistake to imagine that the fresh air drawn through the pipe by the cowl has more power in drawing air off from the rooms than the direct action of the cowl would have on the outlets from these rooms. For all purposes, however, of insuring the proper action of foul air shafts, especially from water-closets, hospitals, prison cells, &c., I think these cowls will prove of the utmost value. One of the great difficulties the sanitary engineer has to contend with is the liability of his outlet shafts, under certain conditions, to play him false and act as inlets, and so to reverse the whole of his carefully arranged sys

tem of ventilation. For smoky chimneys I know that they have proved most successful, in cases where almost every known contrivance had previously been tried without success.

The proposed application, however, of these extracting cowls to the ventilating pipes carried up to the roofs of houses from the drain pipes, as advocated by Mr. Banner in his pamphlet, so as to draw constant currents of air through the sewers and street drains, appears to me to be founded on a principle which will not bear investigation. That such outlets for the gases produced in the sewers ought to be provided, there can be no doubt; and I will go further, and say that there ought to be power to compel everyone who builds a house in future to make such a provision; but I think that such outlets should be regarded as safety valves, and should be allowed to do their own work, without the assistance of any extracting cowls, which would simply aggravate the evil, and turn our sewers into great underground gas manufactories. You do not want to promote decomposition, and so to increase the production of sewer gas, but merely to prevent the dangers arising from its being pent up in the drain pipes. Those who know how lighting gas is produced, by merely drawing or forcing air through underground tanks of petroleum oil—where, in passing over the surface of the oil, it picks up the vapor which enables it to burn with such a brilliant light—will see, at a glance, what will be the effect of drawing streams of air through sewers and drain pipes, and discharging them perpetually into the atmosphere, to be blown into our houses, and to contaminate the air in our streets. We must not strain after too much, a sewer must always be a thing of dirt, and there is no necessity to turn it into a desirable place of retreat from the heat of summer, or the cold of winter. Already we are told by analysts that the air in some of our London sewers has been found to be quite as pure as that which the fashionable world are content with in many of their haunts of pleasure, and, if we can attain to such a standard throughout the whole of them, we need not mind if the street gullies sometimes act as outlets, and the ventilating pipes up our houses as inlets. If we only provide the requisite openings, and construct our drains and sewers properly, the intermittent flow in such underground channels, driving out air and sucking it in, as well as the never-failing law of nature, in obedience to which the lighter gases must rise and give place to the heavier, will keep the air within them in such a constant state of motion that all the evils which are laid at the door of the water carriage system of house drainage will vanish, and we shall wonder that it could ever have been seriously suggested to relieve the waste water from the duty, which it so cheaply performs, of carrying our solid sewage far away from our houses and towns.

Before concluding, I must say, in justice to Mr. Banner, that having no professional knowledge of sanitary engineering or sanitary science, the greatest possible credit is due to him for having succeeded in solving a problem which has hitherto baffled all the combined talent of the best sanitary authorities of the day; and that, whether we choose to adopt his system in its entirety or not, he has certainly taught us something that, however well it was known before in theory, no one has been equally successful in applying in the more valuable form of practice.

ARMOR-PLATES AND PROJECTILES.

From "Iron."

Experiment was made recently at the great works of Charles Cammell & Co., at Sheffield, which, it is believed, will have an important influence upon the future of our own and other ironclad navies. It was the rolling of the thickest armor-plate which has ever been produced. It marks another stage in the almost endless controversy in which the penetrating power of guns is set up against the resistance of armor-plates. Four and a half inches is the thickness

of the plates with which vessels of the *Warrior* class are covered. Step by step the size has been increased till it has reached 14 inches, which, until then, was the thickest plate known. Messrs. Cammell & Co. have now succeeded in producing one of 22 inches, this being eight inches thicker than any armor-plate ever yet rolled. The plates, of which this is a sample, are intended for the *Dandolo* and *Duilio*, two war vessels now being built in Italy for the Italian Government—one at their dockyard at Castellamare and the others at La Spezzia. These vessels are to be armored at the water-line with plates of this thickness, and the representative plate rolled lately was ordered from C. Cammell & Co. for the purpose of ascertaining the relative resistance of plates of this enormous thickness compared with the thickest that has yet been manufactured. The gun to be used in testing this great plate is one of the 100-ton guns now being made by Sir William Armstrong & Co., at Newcastle. The vessels are to have two turrets, and each turret will contain two of these enormous pieces of artillery. The guns will be about 30 feet long, their bore 19 inches in diameter, and they will throw a shot weighing nearly one ton. Several hundred pounds' weight of powder are necessary for each charge. One of the guns is nearly ready, and Sir W. Armstrong has been specially asked to make a crane capable of lifting 150 tons to move it. To give some idea of the enormous mass of metal of which the plate is formed, it may be stated that it had to be in the furnace upwards of twenty-seven hours before it was fit to be placed upon the rolls. It weighs upwards of 35 tons, and measures 17 feet in length and 5 feet in width. The experiment of rolling such a monster was a bold one. Sir Joseph Whitworth, Sir W. Palliser, and a number of officials and diplomatists were present to witness the operation.

Before the plate was rolled, a luncheon was served at the works, at the conclusion of which a few toasts were given and responded to. Sir Joseph Whitworth's health was proposed in connection with his guns. In giving it, Mr. Cammell stated that if Sir Joseph's guns succeeded in penetrating the plate about to be rolled, he should have no hesitation in rolling one of 30 or even 40 inches in thickness. In reply, Sir Joseph Whitworth kept significant silence with regard to what he believed his guns would do when opposed to a 22-inch plate. Sir William Palliser's health was also given. In replying, he said, that owing to the success of his projectiles, he at first thought that the days of iron-plated vessels were numbered, and that we should return to unplated ships with heavy guns. Subsequent experiments, however, satisfied him of the enormous resistance which armor-plates presented to projectiles, unless they happened to strike obliquely at right angles, and it was this enormous resistance that, in his opinion, rendered the retention of iron-clad ships necessary to the country. Nobody could yet say whether the gun or the plate would win. If Sir Joseph Whitworth made a gun that would penetrate even a plate 22 inches thick, then a plate must be made that it could not penetrate ; in fact, the bigger the guns, the more powerful must be the plates. Nobody could deprecate more than he the idea that, because of the increase in the power of penetration of our guns, iron-plated ships must be abandoned. What they required was that their plates should be more powerful. It was only in direct firing that the greatest penetration had been obtained, and it was but fair to presume that in actual warfare the greatest portion of the shots would be fired obliquely. He was quite aware that Sir Joseph Whitworth had invented a shot which would "bite" when fired from an oblique position, but even then the penetration was much inferior to that obtained by a direct shot. That being so, he was inclined to think that armor-plated ships would always possess an advantage over guns.

Shortly afterwards an adjournment was made to the armor-plate mills. A group of men were standing round the furnace in which the plate was being heated, and at the word of command from a superior they began to pull away the bricks at the mouth of it. Instantly the flames leaped out, and the men, accustomed as they are to stand a great heat, were constrained to retreat until the fury of the flames had subsided. Then one wearing only trousers and a shirt

approached the furnace, raised a little doorway, and looked at the huge monster within. The view was doubtless satisfactory, though how any one could look into this furnace unscorched was a marvel. Men were then seen guiding up to the mouth of the furnace a huge pair of tongs with which the plate was to be grasped. A trolly, too, was sent almost up to the mouth of the furnace, which, by and by, received the plate when the tongs had done their work. Everything was now ready. The door-way of the furnace was lifted up, the flames shot out and lit up the mill, and while spectators shielded their faces with their hats or handkerchiefs, the workmen, with their backs to the furnace, pushed up the tongs until they grasped the plate within.

Balks of wood were then put on each side of the furnace to enable the plate to be drawn out the more readily; but the flames seized upon them and appeared to devour them as if mere shavings. There was no time to lose, the order was given, and the machinery began to move, the chain fastened to the tongs, slowly tightened, and the huge mass, which had required twenty-seven hours in such a furnace as this before it was "done," made its appearance. Fierce as had been the heat before, it was now ten times greater. One could look upon the plate, white with heat, over and around which little blue flames appeared to be lingering. Slowly it fell upon the trolly, the tongs were then removed, and in a moment or two the rolls, which had been revolving for a while, caught the end of the plate and the huge mass, weighing 35 tons, passed between them with as much ease as if it were but a $4\frac{1}{2}$-inch plate. Backwards and forwards it came six or seven times, each time the distance between the rolls being decreased, and the operation ended as soon as the required size had been attained. The rolling was most successful, and it is believed the plate is without a flaw. The destination of the plate is Spezzia, where the test is to be carried out.

The experiment shows that there is absolutely almost no limit to the thickness at which armor-plates can be made. It was no idle boast on the part of Mr. Cammell when he said that if Sir Joseph Whitworth's gun penetrated this plate he would make one 30 or 40 inches thick. The result of the test at Spezzia will be watched with great interest.

HARDENING AND TEMPERING GLASS.

From "English Mechanic."

The well-known Dresden manufacturer, Herr F. Siemens, has recently patented a method of hardening, tempering and pressing glass, which appears likely to become of more practical utility than the process of hardening discovered by M. de la Bastie. At the time when the latter's discovery was made public it was announced that Herr Siemens and others had been experimenting in a similar direction, and the accusation was freely made that Bastie's process was being pirated. Whether or not it is so in Germany, the process described by Herr Siemens in his English specification certainly keeps clear of the "claim" put forward by M. Royer de la Bastie, for he does not employ the method of hardening glass by plunging it when heated into a liquid bath at a lower temperature, but hardens the glass by placing it in moulds and pressing it at the same time. It was obvious at the time when M. Bastie's process was made public that great if not insuperable difficulty would be experienced in getting the glass to retain its shape during the hardening operations, especially so with articles that required to be shapely to be of any value at all. Whether these difficulties have been overcome we are not informed, and as there are already several patents relating to hardened or so-called unbreakable glass in the field, unless M. de la Bastie speedily occupies a position in the market he may find himself forestalled. At any rate it is asserted that the process patented by

Herr Siemens effects all that could be done by M. de la Bastie's, and more, for the shape of the articles, can be easily preserved uninjured. It consists in a method of heating and then suddenly cooling the glass to be hardened or tempered; but when the articles are such as are usually moulded, the hardening and tempering are accomplished at the same time as the pressing—*e. g.*, the molten glass is run into suitable moulds and while still highly heated is squeezed, the moulds having the effect of giving the necessary cooling without resorting to the liquid bath of M. Bastie. The material employed for the moulds depends on the nature and thickness of the glass; in cases where the cooling process must necessarily be a rapid one, metals of good conducting power, such as copper, are preferred, while in those where the cooling has to be effected more gradually moulds of earthenware, or other bad conductors of heat are employed. In cases where the glass articles to be operated upon vary in thickness the conductivity of the parts of the moulds is varied accordingly, either by means of thicker metal near the thicker parts of the glass, or by making those parts of the mould of a better conducting material than the parts next the thinner portions of the glass. The moulds, too, must be kept at certain temperatures varying according as the nature of the glass requires that they should be cooled to a greater or lesser degree. In ordinary practice, however, it is found that cast-iron moulds maintained at a temperature of boiling water or thereabouts, and earthenware moulds kept quite cool, yield very satisfactory results. The liquid glass may be conveyed direct into the moulds, or may be taken from the melting-furnace on the blower's pipe and shaped in the mould, but it is preferable to heat the articles after shaping or partial shaping before pressing and cooling them. This part of the process introduces the difficulty of keeping the articles in shape, and it is overcome by Herr Siemens by means of casings or shells of platinum, such shells being transferred to the mould with the glass to undergo the pressing and hardening process. The heating ovens may be of any suitable construction, but Herr Siemens prefers to employ regenerative gas muffle ovens, heated under the floors and over the crowns by the flames of gas and air, which pass from one set of regenerators to another, which latter becoming sufficiently heated the currents are reversed in the well-known manner of alternated working. The muffle being completely closed in, the articles are protected from dust and other impurities which in the open furnace are apt to settle on and damage the surface of the glass.

The lower halves of the moulds are mounted on trucks or hand carriages, and are run up to the furnace mouth or the oven, as the case may be, and having received the glass are run under the respective upper halves, which may be loaded to give the desired pressure. The temperature of the moulds is kept at the required point by supplying them with liquid, and water at the boiling point is found to be well suited for the purpose. Herr Siemens claims the process described of producing hard pressed glass by treating it whilst heated in moulds at a lower temperature, whereby it is simultaneously compressed and hardened. He also claims the use of moulds having parts of varying thickness, or of different materials having various degrees of conductivity. A separate claim is also made for the use of the platinum moulds to maintain the articles in shape whilst being heated in the muffle. Whether the process of M. de la Bastie or that of Herr Siemens yields the best results no evidence is at present forthcoming, but there can be no question that a large demand will arise for unbreakable glass as soon as it can be supplied.

It appears from an official return that, during the year 1874, there were built in London 7,764 new houses and 145 new streets, and two new squares were formed, the length of the new streets and squares being 22 miles and 862 yards. 3,542 new houses were in course of construction. The length of new streets and squares opened during the last quarter of a century is 1,181 miles and 54 yards. "There does not appear," adds the return, "to be any immediate prospect of a cessation of growth of buildings; the tendency is rather the other way."

GEOGRAPHICAL SURVEYING.

By FRANK CARPENTER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

LET it be supposed that we, that is, the reader and the writer, have received commission from some state or national government to organize and prosecute the geographical survey of some portion of its wild and and unmapped domains; in this thesis the writer will submit to the reader a project for the execution of the same. Whether this territory lie in Australia, Arizona, or Alaska, will affect us only in the material of our outfit, and not in the methods of our work, which are the same wherever physical laws prevail and the face of Nature is wrinkled with mountains and valleys and furrowed with the river-bed and cañon.

In this problem, we have given us a certain sum of money, a limited period of time, and a stated area of territory of which we are required to furnish the most accurate and impartially complete map that our means will allow. The work is peculiar and difficult. It is a branch of our profession for which no training-school prepares its student and no text-book can instruct him. This is a field in which the experienced topographical engineer, fresh from his labors on park, harbor, and landscape, finds himself unhandy and incompetent, for much of the experience and tradition that he brings with him is an incubus to retard him. To become efficient in this new service, he must forget much of the rule and routine that he has learned, accustom himself to taking broad and bird's-eye views of the country, and, strange as it may sound, he must make it a matter of duty and pride to neglect much that is near at hand, remembering that, although a mole-hill at a distance of a few feet, subtends a greater visual angle than a mountain as many miles away, yet it is the mountain, and not the mole-hill, that deserves delineation on his map. Whereas he has been local and narrow in his range, he must now become geodetic, else he will accumulate a mass of minutiæ, whose representation would be infinitesimal on a plot of the proposed scale, and which is hence but an incumbrance to his books, and worse than cumbersome, inasmuch as its presence excludes other and more valuable data. In short, the topographer views the earth as a microcosm, but the geographer is a man of no such narrow horizon, and trains himself to look upon it as a macrocosm.

Of scarcely secondary importance to the men of our corps are the instruments with which they shall work. The tools which have been devised for the ordinary surveys of land and landscape must be left at home with the slow and tedious methods from which they cannot be divorced. In a work of geographical extent, the level, chain and tally-pins, are out of place, and whosoever, making accuracy his plea, attempts to introduce them there, finds his own ends defeated by them. Once upon a time, for instance, an engineer was intrusted with the survey of a large tract of new territory. The time and resources assigned him would allow him to touch the country but lightly and by swift marches, but, as this was intended to be only a reconnoisance, nothing more was expected of him than to trace the conformation of the land in a general way. He was an honest and conscientious engineer, and so great was his zeal for accuracy, or nicety rather, that he was scrupulous to a fault. He employed the spirit-level in determining the heights of stations along the route, whose distances were found by stadia measurements, which system, though considered incautiously rapid in topography, is too laggardly slow for geography. In this manner he crossed his territory with a few lines of march whose profiles were as trustworthy as those of a railroad survey, and far more accurate than the public interest demanded, while between them there were areas untouched and unseen, and of these the public, whose agent he was, had commissioned him to obtain information. The failing of this engineer is a common one; he neglected

to distribute his resources fairly and impartially, and, while half of his map is reliable the other half is conjectural.

To enumerate and describe in detail all of the instruments whose use is peculiar to the making of geography, and to rehearse the devices employed in its successful prosecution would be material for a volume; however, a few of the most necessary and novel features will be noticed in the course of this paper. At the basis of the work is the transit, or theodolite, which, with compass attachment, is the engineer's *vade mecum*, without which his occupation is gone, no matter in what field his labor may lie. As an appurtenance to this, not the chain nor the stadia, but the odometer wheel, has become the recognized means of mensuration in the meander of streams and the determination of those distances of route and detour which are so useful in filling in a triangulation chart. Instead of the level the cistern barometer gives the heights of mountains, mines, passes, camps, settlements, and other important positions, while the aneroid barometer, portable as a watch and as easily read, will tell the altitudes of minor points and give with sufficient closeness the data from which may be plotted the profile of the odometer's itinerancy.

These are the three classes of instruments that are indispensable; to carry and operate them three men are necessary, the topographer, the meteorologist, and the odometer recorder. Any addition to this number, except as military escort or muleteers and servants, or as an executive officer who shall also be purveyor and guide to the marching party, would be superfluous, as one surveyor can see as far as two, and one man is able to note all of the topography visible from his route of travel. No axemen are needed, for if there is a tree in the way the line must yield to the tree; the resultant error will be trifling, and will not be apparent in a map which represents several miles of territory on one inch of space. Neither is there any necessity for rodmen, with rods of two targets for micrometer measurements or one target for levels, who retard the corps by the long delays consequent to their change of base from stations aft to front; as it travels this party is a unit, moving as fast as their animals can walk, and is never broken, a consideration which is of value in a country of hostile people. Of course the scope of the work may require the service of a great number of professional men, but its best progress demands that they should be divided into corps of the above size, which shall work in concord and under one general head, making rendezvous from time to time for the comparison of notes, reorganization, exchange and issue of supplies, etc.

Guided by these thoughts, let us suppose that we have completed our organization for a season in the field and that we are now on the ground ready for work, at the place selected as the initial point of the survey. As with all surveys, this one will be executed from stations, meaning thereby any points at which a tripod is planted and an instrument adjusted, angles are read and sketches are made. Of these we shall occupy four classes, of which, in importance, and consequently in accuracy, the astronomical is first, and then come the geodetic, or primary triangulation station, the topographical station, which is an apex for subordinate series of triangles, and finally the meander, or route station. These with the incidental details pertinent to them, will be considered in the order named.

Since the positions determined by triangulation, or by any system of survey in which terrestrial objects alone are considered, are only relative to each other and to the first station occupied, it is evident that a map may be completed, which, *per se*, will have all of the exactness of perfect truth, but whose place on a projected surface of the globe will still be uncertain. A map of a continent may be made, and this may be of great use in the guidance of travelers, across the continent, and for the local information of its inhabitants, but still it does not play its proper part in the grand plan of this earth's geography, and define the situation of this land relative to the other continents of the earth, until it is bound into place by the meridians and parallels, which are the warp and woof of the structure of geography. Therefore, in order to adjust our map, when made, into its true place, we must

have the absolute determination of one or more of its positions.

Now there is but one way of finding the absolute position of an object on the earth, and that is by going beyond the earth, consulting the stars, and ascertaining its place relative to them. Having two triangulation stations thus located the whole chart becomes adjusted to its place. Or, having the latitude and longitude of our initial point and the astronomical azimuth of the side of a triangle leading from this origin, the former serves to pin the plot to the projected map, and the latter is instrumental in orienting it into the area to which it belongs.

It is probable that our point of outfit is on the verge of some civilization, and perchance it is connected by telegraph with some national observatory, whose longitude is known. If so, a series of exchanges with that observatory and a series of observations for latitude, extending through a couple of weeks, will, in auspicious weather, be enough to determine with sufficient accuracy the geographical co-ordinates of our point of departure. This can be done by the astronomer while the engineers are measuring the base-line and developing the same, the director is perfecting the organization, and the purveyors are distributing the instruments, supplies, and all of those numerous articles of equipment which are the furniture of a scientific field season. At the same time the meteorologist, by a set of hourly barometric readings, accumulates data whose digest will give the vertical co-ordinate of this place with a possible error of a very few feet, and this completes the determination of its position with reference to a system of three axes whose origin is at the level of the sea at the point where the first meridian crosses the equator.

An inland survey, based upon trigonometrical methods, progresses most successfully from an initial point concentrically outwards. The most fortunate location for this initial point is in the centre of some broad valley or intermontane plateau, whose level expanse offers fair ground for the measurement of the base and whose open field is favorable for the gradual and symmetrical development of the same until it shall reach the lines of the remotest triangles, in which it becomes a metrical standard for finding their length. In an extensive survey, lasting for years and covering broad territory, a series of bases are indispensable. These act as checks upon each other, and the net-works of triangles emanating therefrom, are dovetailed into each other, and, in their adjustment to fit each to each, what little of error may have accumulated is reduced to a minimum. For instance, on each side of a continental divide there is an open basin. In each of these an astronomical station is established and a base is measured. On the comb of the intervening sierra, one hundred miles apart, stand two preeminent mountain peaks. The latitude and longitude of each of these, with the distance between them, is determined from the two origins independently. They check each other, and this long line, drawn by the labor-saving appliances of trigonometry through a hundred miles of aërial route, a mile above the valleys and chasms which it spans, joining the peaks like a fine spider's web, is now ready to be used as a new base in the primary triangulation.

The ground upon which a base-line is to be measured should be as smooth and bare as possible ; whether it is level or not is a matter of secondary importance, as correctness may be easily applied to cancel the effect of its gradients. In its direction and position it should bear judicious relations with certain knolls, knobs, or buttes in the vicinity, which may be selected as sites for the stations to be occupied in its development, the plans for which should include some two prominent peaks in the horizon, remote from the origin and distant from each other. Owing to great exposure to the wind, or to inconvenience of approach, it may not be found practicable to locate the astronomical station at any of the points of the triangulation system, or, to secure proximity to the telegraph, whose office may be hidden in the heart of a town or the bottom of a valley, it may be so secluded as to be invisible from those points. If so, it may be easily connected with them by running a careful traverse from the astronomical station to the nearest geodetic station, and, from the results of this, computing their difference of latitude and longitude.

The length of the base may vary from one to five miles. In the opinion of many engineers more than two miles of measured length is zeal gone astray, for the advantages of accuracy gained by such excess would be obtained more easily by devoting the extra time to a more elaborate trigonometrical development. Since rapidity as well as accuracy is an object, we use a steel tape, fifty feet in length, which is fitted with a micronometer screw, adjustable to compensation for any possible change of temperature, and also with a dynamometric attachment to govern the tension applied. The measurements may be made on wooden plugs, which are driven into the ground along the alignment at intervals equal to the length of the tape. When all things are ready this line of two miles in length can be easily measured once over in one day. However, since the best tapes manufactured can be but inefficiently compensated for temperature, and since the best assistants are liable to a personal equation in sticking the marking pin, some invariably inserting it to the right of perpendicular and others the reverse, it is well that it should be measured several times and by different persons, and a mean of the results taken. Then it should be leveled, corrected for gradients, and finally reduced to the length of a concentric arc at the level of the sea, when it will be ready for use in the system of triangulation.

In the early stages of the development of this base, occurring on the level of the plain, it will be found necessary to use artificial signals. Great tripods of framework are erected and each of these is furnished at the summit with a flagstaff, to which voluminous folds of white muslin are nailed, while the body of the steeple is wrapped with the same material and decked with loose tatters and streamers, which, by their ceaseless flutter in the wind, offer occasionally a surface from which the light is reflected to the eye of the distant observer. These stations should be erected in conspicuous places, on high ground or the salient angles of bluffs, that the observer may know where to direct his instrument in searching for them, as it is extremely difficult to pick out the faint glint of a few yards of muslin on the broad white surface of a remote plain. As the development continues and climbs from the foot-hills into the high and peaked mountains, these natural points are sharp and distinct enough, and the labor of station building ceases, except in cases that are very unfavorable. True, this triangulation by natural points is not so precise as it is in our surveys of coasts, where even the phase of the conical signal is considered too important an element of error to be neglected, nor is it wise that it should be so, for a fault of a few feet, or even of a hundred feet, in the position of a mountain top located by this plan is of no practical consequence, and greater expenditure for greater accuracy is something which no people can afford. A mountain is only a land-mark by which travelers are assured of their place and are guided as they go, and to men who travel by land a fraction of a mile is a deviation which they cannot notice; to the voyager at sea, however, who may be wrecked at any moment, the exact site of the sunken rock which he shuns should be known to him, in order that he may certainly avoid it. This is why the coast and inland surveys are so different in the amount of cost and the degree of accuracy which characterize them.

It is now time for us to occupy our typical triangulation station. This may be a mountain 14,000 feet in height, whose summit is above all vegetation and in the belt of perpetual snow. It will be ascended by the engineer, the meteorologist, and such assistants as may be necessary to carry the implements of the work and the food and water for the maintenance of the party, and to build the stone monument which is to crown the mountain and receive the records deposited here. On account of the privation and exposure to which the corps is subject the time of occupation cannot well exceed one or two days, although, if possible, one night should be spent on the crest and devoted to the determination of the azimuth of some line radiating from here. Since the time is so short the observer should make all reasonable haste in his operations. Especially is this so in his sketches, over which he must not linger, which, if he is anything of an artist, he will be sorely tempted to do. He may see before him broader views and scenery more grand

and impressive than ever was painted yet, but picturesque effects are no business of his. To the topographer of artistic tastes there is great temptation to finish his sketch by inserting a pine-tree in the foreground, and, perhaps, an eagle's-nest in the tree ; this is all very wrong, for such dalliance may cost the omission of that far distant peak, which is printed like a fine point against the horizon, and which, insignificant and low as it appears, is yet of vital importance to his scheme.

His sketch is perforce but the outline and skeleton of a picture. Two converging straight lines, with a stroke or two of shading hastily thrown in, are sufficient to represent the ordinary mountain peak. Yet, if this peak should possess any oddity or strong individuality of shape, this feature should be magnified in the drawing, and remembered as a key to the identification of this point when seen from elsewhere at some other time. In general the telescope is directed to the highest part of the mountain, which has been selected as a correlative station, because that is the spot which can be most easily identified, either from a distance or on the ground itself, but if this place should be uncertain, as where there are a number of pinnacles of equal altitude, or not sufficiently pronounced, as in a plateau summit, some peculiar object, as a lone tree or an isolated bowlder, should be chosen as a center upon which to sight. If the mountain is low and covered with timber it may be absolutely necessary to send axemen in advance to clear away all but the largest and most central of the trees of this forest. Since any mountain, when seen from different points of view, presents phases that are quite dissimilar, it is one of the greatest difficulties of triangulation to make sure of the identity of a station previously occupied, or, where there are a number of observers in the same field, to secure uniformity in the choice of the same.

The expert geographer is proficient not only in profile but in contour drawing, and on every mountain station he executes a contour plot of that scope of country which he sees beneath his feet, and of whose conformation he is certain. This completed, he reads angles for the direction of the spurs which project from here, and estimates with enough closeness such distances as may not exceed ten miles. But in the preparation of this local plot he should not be too comprehensive, and go beyond the bounds of certainty into the outer limits of conjecture. Every mountain is surrounded by valleys, on whose farther side are other ranges perhaps as high as this, and they form the limit beyond which no contour sketch should presume to go, else it becomes conjectural and unreliable. It may include those environs of valleys with a periphery of the foot-hills which are there *enceinte*, and a tracing of the cañons which indent the same, but no more. In the office a contour sketch is accepted as truthful evidence of the country as it really is, while a profile drawing is considered only a copy of the land as it appears to be, when uncorrected for the illusions of perspective, and is studied and deciphered accordingly. Looking abroad from this station, the successions of distant ranges, which are in reality separated by broad interspaces of valley and plain, are projected into a dense and circular wall, apparently unbroken by pass or intermission, whose serrated outline is seemingly as continuous as the horizon ; it is an error to which the human eye and judgment is subject, and so, in orographic delineation, the impressions of the eye are to be received with caution, and only the readings of the theodolite are to be accepted in full faith.

The instrument of triangulation is a theodolite, whose accuracy and weight increase with the minuteness of its graduation, but, in this rough and laborious work, there soon comes a limit beyond which it is imperative to sacrifice nicety to portability. This is reached when the limit is graduated so as to discriminate to ten seconds of arc. With this the observer reads and repeats the angles, singly and in combinations, which lie between the visible points of the triangulation scheme, choosing for this important task the most opportune moments, usually in the evening or early morning, when the sun is behind the hills and the rim of the earth is seen in silhouette against the rosy background of the sky.

In addition he takes single readings to subordinate geographical features, which,

although they may never be occupied for the purpose of reciprocal observations, may yet be located by intersections from two or more triangulation stations. Sights are taken to the junctions of streams, the mouths of canons and to the heart of a distant village. Some point, or "tit," standing on the edge of an abrupt bluff, where the rapid descent begins, is used as a means of marking the end of a neighboring mountain range. A promontory, jutting into the confluence of two rivers, is instrumental in fixing the place of their union. A solitary butte on the plain, insignificant in itself, is very useful in determining the locus of the stream which flows by the side of it. A spot of green on the desert, evidence of a spring of water there, is located, for it will probably some day be camping-ground for him or his co-laborers. A minute patch of white lake-bed, or alkali flat, or red escarpment, is sighted upon, because on such a day he made a meander station there, and this sight will serve to check its position. In his note-book and mind he has dubbed all of these things with graphic titles, or designated them by letters of the alphabet, and by these tokens he will know them when he sees them again. But this system of names is only a transient device for the assistance of himself and those who work in concord with him, and must not appear upon the printed sheet, which is no place for the arbitrary nomenclature of any one man. Perhaps the modern geographer is guilty of no more common and high-handed outrage against right and beauty than by ignoring the appropriate and beautiful titles which abound in every country, however wild and uncivilized, and attaching his own, or, by mutual and tacit agreement, his comrades' names, to the mountains of that land, thus announcing themselves to the world as nostrums are advertised on the pyramids.

All of the preceding description which does not refer directly to the triangulation process is also pertinent to the topographical station, which may or may not be a point in a subordinate scheme of triangulation. Of course, it is desirable that every occupied station should subsequently be made an object of reciprocal observations and thus become a center of a plexus of triangles, the computation of whose sides will admit of the elimination of error and the distribution of spherical excess, and the observer should neglect no opportunity to confirm his position in this manner. Still the predominant idea of a topographical station is that it is a means of local topography. Angles are read to three or more known points, or triangulation stations, of which there are usually a number visible, which data, being plotted, are sufficient to fix the station in its proper place on the projected map. Then by lines of sight, which shall be intersected by other lines of sight from other topographical stations, the most prominent features within a radius of twenty or thirty miles are located, and, as a precaution, bearings are also taken to all eminent points at a greater distance, even to the horizon, as they may come into use in some future dilemma of map-drawing.

Thus it will be seen that every hill, however humble and inconspicuous, may be used as the site of a topographical station, provided there be three known points visible, and that the surrounding vista be not too narrow. A few hours are enough for its occupation, and the route between points of triangulation should be marked at regular intervals by the monuments of these stations. A topographical station in the streets of a settlement, or at the end of a mountain range, will locate these important places, and in camp, even in the center of a broad plain, there is no more profitable manner in which the topographer can spend the hour or two of leisure time after dinner, than by making a topographical station there and locating his position. Every camp thus fixed is a new initial point at which the meander of the next morning will begin.

The meander survey is useful in tracing the path of defiles and water-courses and the route of roads and trails, in determining the distances between springs of water, villages, valleys of pasture, fords of rivers, and other such information of interest to the future traveler, and finally as a commendable occupation for the engineer who is on his way from one mountain station to the next. In the theoretical journey of this kind, the engineer would follow the edge of the

dividing ridge from one peak to the second, from which lofty promenade he could see the earth like an extended scroll beneath his feet, and make a survey which would be exhaustive and complete. But in the real, hard practice, he finds this path an impracticable one, for it is broken by precipices and blocked by abutments a thousand feet in height. His easiest route of travel is by the side of flowing water, whose tendency it is to erode abrupt cliffs and soften steep gradients into an average and even slope. Besides, along the streams there are trails made by the wild animals which come here for drink and covert, and by the wild men who come hither to hunt and fish. Therefore, if the detour be not too great, the most expedient route from mountain to mountain is down one valley and up another, and the topographer, who traverses a valley without taking some sort of a survey of it, is almost criminally negligent of his duty. On the other hand, if in a block of mountains the preeminent peaks be occupied, and the streams which emanate therefrom be meandered, nothing more is needed for a most excellent topographical map of that country.

It is supposed that all travel and transportation of outfit, except in the ascent of high mountains, is accomplished on the backs of mules, which are the only animals that can endure through the vicissitudes of so hard a life. Riding in the saddle, the surveyor can devote but one hand to the grasp and protection of his instrument, the feet of whose tripod rest in a holster attached to the left stirrup. To facilitate his secure hold, the members of the tripod are thirds of a cylinder, which fold into the smallest possible compass, and are easily held in the grip of a hand. The instrumental part of the meander transit is neat, solid, and compactly constructed. Its graduated limb is of small diameter, and its horizontal vernier reads only to minutes, which is all very well, since no smaller divisions can be plotted on the map. This graduation is used in the occupation of topographical stations and at meander stations, where the view is extended enough to make it profitable to linger an hour or so in the accumulation of notes and sketches. Since the meander survey is from its very nature so hasty and loose, the system of frequent checks can alone make it valuable, and at intervals of every few miles, at every camp if possible, and especially at the crossing of divides and other eminences from which known points are visible, stations should be accurately located by the three-point problem. Each of these then becomes a new initial point, at which the survey begins afresh and the error again begins to accumulate.

The meander is affected by error of two kinds, of direction and of distance. The former is incurred in the survey of a tortuous valley, whose general course must be guessed, or in crossing a timbered country or pathless plain, where the surveyor is in a constant state of uncertainty as to whither he is to go, or, taking a back-sight, as to whence he has come. This error, it will be seen, is thrown by the law of chance alternately to the right and left of the true line, and so has a tendency in its elements towards mutual compensation, and in a measure it corrects itself. But not so the error of distance which is always plus and cumulatively so. The test of the odometer wheel, by which its number of revolutions per mile is ascertained, is made upon a level surface and along a staked alignment, giving a result almost absolutely correct. In practice, however, the vehicle climbs acclivities of every grade, tacks hither and thither as it follows the trail up the mountain, winds incessantly in its route through the forest, and is disturbed by frequent jolts and collisions along the rocky floor of the cañon. Hence an "overrun" in its record, which can only be remedied, and that approximately, by the judgment of the surveyor, who is taught by experience to estimate very closely the surplus in a given run, and who applies a deduction accordingly. To such perfection has the odometer survey been brought that it is no uncommon occurrence for a skilled worker to meander a closed circuit of a hundred miles, and, plotting the route, to find the plot also close within a fraction of a mile.

In the general traverse not the vernier plate, but the compass needle, on account of its greater convenience, is used, and nightly observations on Polaris, at or about its elongation, give the basis for computing the magnetic variation at

each camp, to be used in the reduction of the meander notes taken in the vicinity of that place. At every camp, also, the fickle aneroid barometers are compared with the cistern barometer, their errors are noted, and the vertical element of the survey starts from a new and true datum plane when the march is resumed. The zone of country included in a meander survey may extend to the farthest visible point, as a series of sights on a mountain even twenty-five miles distant will give its position to a close approximation, but its principal intent is the preparation of a narrow route map, the areas encompassed by whose windings will be filled in from the topographical stations.

From its nature and narrow scope, the meander survey is fuller and takes cognizance of objects more minute than can be noticed in the other systems, and in this the engineer is liable to a charge of partiality, reproved in the early part of this article. But this is not partially in one field at the cost of neglect in another, and the greater excellence of this work is so much clear gain. Moreover, since the meander is usually by way of roads of frequent travel, and since a map is useful, and should be excellent, exactly in proportion to the number of people who are guided by it, it is well that the meander plot should excel in completeness the representation of those almost inaccessible parts which will never be seen except by the hunter or bandit. On the same principle, in the United States geographical surveys, tributary to the War Department, whose maps are on a standard scale of eight miles to the inch, it has been deemed a matter of public economy to represent on one inch of space sixteen miles of some territory, as, for instance, on the level and vacant plains, while in other regions four miles to the inch will barely do the country justice, and in rare instances, as in rich and rugged mining districts, one inch of space is allotted to two miles of ground. In these surveys, which, under the direction of Lieutenant Wheeler, have attained to a most honorable organization and efficiency, material assistance is rendered by the executives of the working corps, who, as army officers, are skilled in the use of the sextant in practical astronomy, and take observations for latitude in the evening at camp. In geodetic surveys, however, the field astronomer is not so essential as he used to be in the old days of "straight-away" explorations and transcontinental surveys, which were too rapid to admit of being rectified by an accompanying belt of triangles.

Every transit, whether for meanders or triangulation, is fitted with a vertical circle, from which to read the angles of elevation and depression of those points which are located by intersections, in order to compute the heights of the same. These angles are recorded as plus or minus, according as the objective point is above or below the observer's station, whose altitude is invariably determined by barometric readings.

The frequency of meander stations in ordinary country will average perhaps one to the mile. In this as in the other departments of the survey too punctilious zeal will defeat its own intents by causing delay, and the surveyor who is too scrupulously exact in the forenoon will have to virtually abandon his task in the afternoon in order to reach camp by night. In a forced march, of twenty-five miles or more, the meteorologist and odometer man, the safe carriage of whose implements requires a slow and steady gait, may proceed at a walk after taking their readings at a meander station, which task will occupy them but a moment, while the surveyor lingers behind to make the necessary sketches and observations, and then, riding at gallop, overtakes his comrades before the next station is reached. Many such shifts as this are known to the practical and energetic topographer, who learns to emancipate himself from those pedantic and common-place rules that are found in books of surveying, and brings into play his powers of ingenuity and invention to adapt himself to the peculiar circumstances by which he is surrounded. If he finds himself alone, out on some trip of hasty reconnoissance, or on some hunting excursion on which he could not carry both rifle and transit, he draws from his watch-pocket an aneroid and from his saddle-bags a pocket-compass or an altazimuth, and his equipment for survey is complete ; as for distances, he can estimate them, or determine them by the time they take, calculating at the

rate of three miles an hour, or, better still, by counting the steps of his mule, and allowing one thousand double paces for a mile.

These are the general divisions and some of the novel features of the geographers work in the field; in the office it is not distinguished above the routine of office-work in general. This thing only may be noticed, that the hand to hand struggle which the field engineer constantly sustains with the forces and obstacles of nature blunts the acuteness of his prehensile powers and makes his touch too heavy for the fine drawing necessary in a map finished for publication, and there should be in every office a superior draughtsman whose hand is accustomed to the use of no heavier implement than the artist's pen. This artistic finish is bought by the sacrifice of accuracy, however, and between the field engineer and the final draughtsman there should be few, if any, middlemen to compile and replot the work, because only the man who has seen the country can produce its physical characteristics with truthfulness. In every copy that is subsequently made the face of the land grows more artificial and ideal, each mountain loses its individuality of shape and assumes a stereotyped and symmetrical regularity which it does not possess in nature, some of the niceties of truthful representation are magnified into exaggeration and others are overlooked and obliterated, the bed of every canon grows broader in each successive transcript, and the large hills grow larger as the little hills dwindle away. As in a popular parlor game a whispered story, passing current from mouth to ear throughout the round of a circle, grows strange and distorted beyond recognition, so in the successive reproductions, of a map by strange hands, it loses its photographic and pre-Raphaelistic truth of execution as the idiosyncrasies of the various draughtsmen are wrought into the plan, and it comes finally to represent a country Titanic and unnatural, made not by the accidents of nature but by the design of man, and moulded by the rules of a regular and rigid geometry.

OVERCOMING STEEP GRADIENTS ON RAILWAYS.

By Mr. HENRY HANDYSIDE.

Journal of the Iron and Steel Institute.

The chief object I had in view, when, in 1871, I first matured the idea of the new system, was to provide a cheap and efficient means whereby the locomotive of ordinary construction might be made available for surmounting steep inclines, and without any alteration or addition to the ordinary permanent way, or alteration in section of rails.

The subject is naturally divided into two parts; the going up, and the coming down, and I propose to describe them in that order.

There is no portion of railway engineering so arbitrary and well defined as the law of inclines.

On all ordinary locomotive lines, the steepest portion becomes "the ruling grade" for the whole line; that is to say, the ruling grade decides the weight of the locomotive, the exact load it can draw on that grade, and the weight of the rails along the whole length of that line, on which that locomotive has to run.

There is no difficulty in apportioning the steam power of any locomotive to the amount of its adhesion, and as this adhesion is solely dependent on the amount of weight which can be put upon the driving wheels of the engine, it follows that the load any engine can take up an incline must be in an exact *ratio* to the weight on the driving wheels, and the angle of the incline.

It has been ascertained, by actual experiment, that the limit of adhesion between an iron tyre and iron rail, is on an incline of 1 in 6; or in other words, any locomotive, with sufficient cylinder power, and all wheels motors, will ascend an incline of 1 in 6.

Any very close approach to this limit would be of little commercial value, and

the nearest which has been successfully employed, is an incline of 1 in 10, which was worked for three years on the Baltimore and Ohio Railway, the engine taking up a load as heavy as itself—this fact is recorded in Mr. Isaac's interesting paper, read before the Institute of Civil Engineers, on November 23rd, 1858.

Thus it appears evident that it is not the steam power of a locomotive that is wanting, but the adhesion between its wheels and the surface of the rails.

To supply this great want has been the object of locomotive engineers from the earliest days of the steam engine, and very numerous and varied have been the mechanical contrivances brought forward, many of them performing all requirements, but laboring under the disadvantage of additional cost to permanent way, greater weight and complication in the engine itself, and all being obliged to elevate their steam power to ascending the incline at the same time with the load.

It is on this point that my system differs from all others ever used. I use any ordinary locomotive, applying thereto a winding engine and steel wire rope, or chain, and peculiarly constructed gripping struts, which also perform the duty of a most powerful brake when descending.

The engine having hauled its train to the foot of an incline, of say 1 in 12, disconnects itself, but leaving the end of the wire rope fast to the train, it proceeds up the incline for any desired distance, but within the limits of the length of the rope.

The struts, having been released by the engine driver, immediately came into play, firmly grasping the heads of the rails, and thus the engine becomes at once a stationary winding-engine. By the application of steam to the winding cylinders the train is drawn up close to the engine.

If the incline is of too great a length to be surmounted in one lift, a similar pair of gripping struts are fitted to the last wagon or guard's van of the train, and as they act quite automatically, the train is firmly held in its place whenever the winding ceases.

This automatic action of the struts, when fully understood, will recommend itself for adoption in all cases where retrogade motion is to be feared on steep inclines; and even on those in this country on some of the main lines ranging from 1 in 40 to 1 in 60, and on which such disastrous results have followed from the breaking of couplings or draw bars.

In laying out a new line for my system, I prefer to keep the steep inclines straight, and within the limit of wire rope the engine can carry. I prefer not to exceed 300 yards, each incline to be followed by a piece of level, which may be taken advantage of for curves. Thus, the ascent of the line is made by a succession of steps, and resembling in its action the working of a canal with locks.

My chief reason for keeping the inclines straight, is to dispense with cast iron guide pulleys, which are objectionable, entailing great friction and wear and tear to the rope; if, however, the nature of the ground is such that the incline and curve must be combined, then the ordinary guide pulley may be resorted to.

When the inclines are kept straight but very few wooden rollers are sufficient, the rope bearing very lightly and only for a portion of the lift; this is due to the rope being coupled to the drawbar of the wagon and the top of the winding drum, at least 3 feet 6 inches from the level of the ground.

It is evident that by this transformation of an ordinary locomotive into a stationary winding engine, it combines and uses all the advantages to be derived from either or both.

Long experience, apart from the theory of the question, has determined the theory of the rope system, and the nearer the vertical lift is approached, the greater the economy of working—but the risk increases in equal proportion.

It is an easy matter to provide against an accident—when going up, either an incline or vertical lift—but the descent has to contend with the formidable powers of gravitation and accelerated momentum.

This brings me to the second part of my subject, "the coming down."

As I have mentioned, I prefer to cut up my line into steps—keeping each steep incline of a comparatively short length. By this means I can reduce the

danger to be anticipated from accelerated momentum; for, supposing the brakes to be overcome, which would never be the case until probably one-third, or one-half of a short incline had been descended, then all the speed any train could acquire sliding to the foot of the incline would soon be overcome when the train came on to the level.

We know by practice that all railway stock has an adhesion to the rail equal to one-fourth of its weight, although many engineers in this country do not think more than one-sixth ought to be relied on.

Taking even the latter as a datum for braking purposes, it is clear that any railway wagon or carriage, with proper brakes on all the wheels, could descend an incline of 1 in 12 with perfect safety, so long as a certain speed was not exceeded, but the great danger is that this speed might be exceeded, even under the charge of the most experienced brakesman, who would have no greater retarding power to apply to, and that train would "run wild."

Foreseeing that this evil must be provided for, I have so constructed my gripping strut that it acts as a brake of the most powerful nature when coming down hill.

The construction of this brake causes it to press, not only on the top of the rails, but also in as great a degree on the sides of the heads of the rails. To provide against wear, the three bearing surfaces of each shoe are made as renewable as pieces of iron or brake metal, which can be removed and replaced in less than 20 minutes.

This brake will work on any section of rail, but it must be apparent that the deeper and flatter the sides of the tops of the rails are the greater will be the effect produced with the least amount of wear on the renewable faces of the brake. Some who have seen the action of this brake, having at once admitted its great retarding power, have qualified the praise by saying it could not be generally available on our lines on account of "points and crossings."

This, at first sight, appears a most formidable objection, but, like every mechanical difficulty, it ought to be, and has been surmounted.

In the case of the application of my brake to a locomotive, Mr. Walker (of the firm of Fox, Walker & Co., Bristol) has made a very ingenious adaptation of steam power, by which the brake is instantaneously and automatically lifted off the rail when coming close to a point or crossing.

A similar arrangement, in the case of a guard's van, can be secured by the use of compressed air, or even by ordinary mechanical appliances.

Although I can fully agree with the general opinion that, "it is desirable that brakes should work equally well over points and crossings," I still think it will be admitted that, although danger is generally to be anticipated in the immediate vicinity of points and crossings that in nine cases out of ten, when brake power has been insufficient, the engines and trains were running on clear rails, and might have been brought to a stand before the points and crossings were reached, if the driver and guard had been in possession of some greater and reliable retarding power.

By the application of this brake to a locomotive, its retarding power is nearly trebled, an advantage of no small importance, especially when under the control of the driver, who is the sole and proper person to have full control over his engine and train.

All the retarding force which can be derived from the top surface of the rails has long been known and utilized to the utmost, as it has often been found insufficient on our ordinary lines, and as it would certainly be quite insufficient on steep inclines, I have ventured to utilize a portion of the ordinary rail which can well afford to take its share of work when required.

My great object in bringing the subject of overcoming steep gradients before your notice, is to prove that by this simple adaptation of certain well-known machines, in combination with various novel appliances, a railway system is produced which will enable the engineer to undertake the construction of mineral lines at a much lower rate than heretofore.

I do not say that the cost, mile for mile, will be less in all cases, as compared with a line laid out with ordinary grades; but it will enable the engineer to take a more direct route, and effect a

large saving in actual distance or length of permanent way—generally as much as 60 per cent., and after giving him the power of taking his line in certain directions to suit the wishes of land-holders, in some cases, thus removing the chances of a strong opposition, which, in several instances, has prevented an easy access to districts, known to be rich in mineral wealth.

BEST TYPES OF WAR VESSELS.

From "Iron."

A HIGH compliment was paid by Admiral Sir R. Spencer Robinson to the "Naval Prize Essay, 1876, on the Best Types of War Vessels for the British Navy" when he occupied five times the ten minutes allotted for speeches at the Royal United Service Institution in defending himself and his late administration from the supposed aspersions of the essayist. Commander Gerard Noel, R N., the successful essayist, is a young officer of much professional promise, who is not unknown to fame. He is not a naval architect, but a seaman; and those who think seamanship ought to be allied to ignorance, should not be shocked if he has fallen into serious errors of detail. The general principles stated by the essayist are at least clearly laid down, and if they had not been worthy of discussion we cannot suppose that Sir Spencer Robinson, Mr. Barnaby, the Controller of the Navy, and so many naval constructors would have assembled to discuss the prize essay.

If Sir Spencer Robinson's argument proved anything, it was that the *Vanguard*, now at the bottom of the Irish Sea, was so perfect a type of war vessel that no improvement, at least from outsiders, was possible. This doctrine of finality is one of the last which Admiral Robinson should uphold. His own practice, and the practice of his successors at the Admiralty, has ever been the reverse of finality. Every ironclad ship built since the *Vanguard* and her sisters, has been not only different from that vessel, but also from its own immediate predecessor. Nobody, indeed, dreams of reproducing a *Vanguard*, or, indeed, any existing ironclad. Mr. Barnaby himself advocated, three years ago, a type of ironclad substantially the same as that suggested by Commander Noel. In fact, the *Nelson* and *Northampton*, now being built, were probably in the essayist's mind when indicating the best type of ironclad. Moreover, Mr Reed, who has never been wedded to finality, in advocating a modification of circular ironclads, shows himself open to a change of type.

Another fallacy relied upon by Sir Spencer Robinson is that a ship of war built for a special object cannot be said to have failed, if she fulfills that object. The whole question is as to the reasonableness and desirability of the object sought. For example, the *Vanguard* (his favorite ship) is built with an exceptionally thin bottom to carry a heavy patch of armor on her topsides; but her bottom ought to have been devised for colliding, inasmuch as she was armed with a ram for the purposes of hostile collision. Yet Sir Spencer Robinson says that the *Vanguard*, at the bottom of the Irish Sea, has fulfilled the objects for which she was designed, and ought not to be criticised by an officer so young in years as Commander Noel.

But the favorite fallacy of Sir Spencer Robinson is that a ship of war is designed solely to encounter a foreign ship of her own special type. This fallacy runs through the whole armaments, as to guns, rams and torpedoes, of the British fleet. And the gallant admiral illustrated this monstrous doctrine by the case of the *Nelson*, our latest broadside ironclad. The water-line of the *Nelson* is protected by 9-inch armor, which also extends upwards at the ends of the battery, so as to protect the crews from raking fire; but the battery is unprotected on the broadsides. The object contemplated by this arrangement is to give thicker armor over the vitals of the ship at the expense of the gunners, and to increase the offensive power of the ship by carrying a heavier weight of ordnance.

Now, Sir Spencer says, in so many words, that the *Nelson* is a splendid ship, but is not intended to fight ironclads whose ordnance is protected by broadside armor. In other words, every British ship is to run away from every hostile vessel which is not precisely of the same type as herself. Sir Spencer forgets that the choice of fighting or running away may not always lie with the British ship. And, can it be for a moment admitted that the *Nelson*, being unable to run away fast enough from a more thickly armored Japanese, South American, or even Turkish ironclad, should strike her colors without trying the fortune of war? When Commodore Nelson, in the third-rate ship of the line, *Captain*, at St. Vincent, singled out a Spanish three-decker of the first rate for close action, he set an example which England will ever expect the captain of the ironclad ship *Nelson* to follow whenever he may be called upon to do so.

Commander Noel's strong point is the sinkability of ironclads, and with this Sir Spencer did not grapple; yet it is vital in the case of vessels built for collision. It belongs to the very nature of iron, as a material for the skins of ships, that it should be much more easily and more fatally perforated than wood of corresponding strength. Thick patches of armor, forming semi-invulnerable targets, protect parts of the ship from shot, but a poke from the smallest gunboat furnished with a snout would send the best ironclad to the bottom. Why, then, are not all the unarmored ships provided with stems shaped for ramming? As it is, British unarmored sloops and corvettes have no choice but to run away from a hostile ironclad; and if their speed be insufficient for successful flight, they cannot avail themselves of such chances of war as remain to them, because their stems are not armed for perforating the thin bottoms of iron ships, their guns are not adapted to penetrating the armored topsides, and they are unprovided with torpedoes. The teeth of the British Lion are drawn, under the idea that he is only to encounter antagonists with hides of similar thickness. Naval encounters occur under countless varieties of conditions, but the chances are very many against special British types of ships ever meeting in action precisely the same classes of vessels. The occasions will be rare in which future Sir Philip Brokes will send written challenges to hostile *Chesapeakes* of similar scantling or armor.

On the one hand, every British ship, of whatever size, ought to have teeth that will bite any hostile vessel from which she cannot run away. And on the other, the bottoms of English ironclads need to be made secure against every puny antagonist.

The Chairman of the Royal United Service Institution has himself had some experience of what a small Irish passenger steamer, proceeding at low speed, can do to endanger the safety of an ironclad. Had that steamer been going at high speed, in rough water in the open sea, Sir Henry Codrington might have had to report the loss of the ironclad *Hotspur*. Some very awkward scratches have been received by other ironclads, the *Northumberland*, the *Defence* and the *Warrior*, for example; which have long shown that ships intended for hostile collision, and specially open to being rammed by much smaller and inferior vessels, cannot collide with even a tug-boat without serious danger.

Mr. Barnaby endeavored to face this point by showing that the new *Inflexible* is to be provided with nine horizontal safety tanks, four feet deep, at the water-line. But these tanks give no more safety than a water-line armor belt. They are simply a target to be avoided by artillerists. A blow below the belt would sink the *Inflexible* as easily as the *Vanguard*, whereas a shot through the upper works may place a few men *hors de combat.* A tug-boat furnished with a submerged prow might send her to the bottom. This circumstance points to an advantage which all small craft ought to be prepared to seize if forced into unequal encounter; and at the same time it points to a great element of weakness to be guarded against.

In short, attention has been so concentrated on the armor-carrying power of ships that their bottoms have been much neglected, both defensively and offensively. We do not think Commander Noel's suggestions as to the cure go far enough. Torpedoes defensively employed ought to be seriously studied with a view to deterring the ramming attacks

of inferior vessels. The towing torpedo lends itself very readily to such defensive employment. And the chances of war between a short, handy English sloop, forced by circumstances to contend against a foreign *Inflexible* and her four guns, though desperate, would not be so hopeless, if the sloop had a projecting prow, that a British commander could be justified in striking his flag before attempting to strike a blow.

Commander Noel is to be the more commended for his essay, that he has fearlessly expressed opinions which officers of higher rank have long held, but which they could not safely express. The gag is so enforced by the system of promotion and the terrors of retirement that few naval officers will run the risk of publicly expressing any opinions on professional subjects. Differing from his conclusions widely on many points, we conceive highly of his method of approaching the subject. And, in any case, an essay which the whole constructional staff of the Admiralty thinks it important to refute in open discussion, cannot be without merit.

The prize has been adjudged by three of the most eminent admirals, and, much as we differ from many of its details, the essay has in it much which calls for serious consideration and high commendation.

ON NEW DETERMINATIONS OF THE VELOCITY OF LIGHT.

Proceedings of the Royal Society.

THE old philosophers and astronomers, until Galileo, thought that the propagation of light was instantaneous.

Astronomical Determination of the Velocity of Light.—Rœmer, a Danish astronomer, called to the Paris Observatory by the illustrious Picard, after having computed from some old observations the eclipse times of Jupiter's satellites, found great discrepancies between the calculated and observed times; the eclipses appear too soon when Jupiter approaches the earth and too late when it goes away. Rœmer ascribed these differences to the time necessary for the propagation of light, and concluded from his observations that light requires about eight minutes to come from the sun to the earth.

Bradley, one of the most illustrious English astronomers, seeking to put in evidence certain small annual motions of the stars caused by the displacement of the earth in space (annual parallax), found such a motion, but quite different from the expected one. The apparent deflection of the direction of a star—for instance, γ Draconis, near the pole of the ecliptic—instead of being at every moment directed, as expected, towards the centre of the terrestrial orbit (the sun), is directed at a right angle. The greatest elongation (called *aberration*) rises to 40.7″ from six to six months. Bradley, after many attempts, ascribed this effect to the composition of the velocity of light with the velocity of the elliptic motion of the earth (1728).

From those observations, and from the approximate knowledge of the distance from the sun to the earth, the velocity of light was found equal to about 200,000 *English miles in a second*, in other terms, *one million times the velocity of sound.*

Direct Determinations of the Velocity of Light were for a long time considered as impossible, owing to the enormous value of this velocity. The first solution was given by M. Fizeau (1849) by the method of the *toothed wheel.*

Induced by some considerations analogous to the celebrated *acces theory* of Newton, M. Fizeau, one of the most illustrious members of the Paris Academy, and recently elected Honorary Member of the Royal Society, succeeded in rendering perceptible and even measurable the duration of the propagation of light for a distance of a few miles.

The principle of the method is the following:

A beam of light passes through the interval between two teeth of a rotative toothed wheel (*roue dentée*): this beam is reflected on a mirror fixed some miles distant, comes back exactly on the same

line, and passes again through the same interval as before. An observer can receive this beam: he will see a luminous point, a *luminous echo*, through each hollow between two teeth: if the wheel revolves with an increasing speed the luminous impression will first become continuous. The wheel will soon revolve with sufficient rapidity to turn a small angle during the time necessary for the beam of light to go and come back again. The angular velocity can be so regulated that the solid part of a tooth is substituted for the hollow part during this time; then, on coming back, the beam will be obstructed by the wheel. The same obstruction will take place at each tooth, and the luminous echo will disappear.

If the velocity of the wheel be doubled, the luminous point will appear again, because the reflected beams will meet with the following hollow and pass through. With a triple velocity a new extinction will take place, as before.

The following apparatus is necessary to produce the exact reflection of the beam:—At each station a telescope is directed to aim at the centre of the object-glass of the opposite station. The beam of light is sent through the first telescope: the pencil of rays, rendered nearly parallel, is received by the second and concentrated in its focus, and there reflected by a small mirror. After reflection, the rays follow exactly the same path, and come back at the very point they start from. The observer can receive these *return rays* without being blinded by the source of light, by interposition of a piece of transparent glass, which reflects a good part of these *return rays*.

M. Fizeau's Experiment (between Suresne and Montmarte) was made to prove that it was possible, not only to establish the duration of the propagation of light, but also to measure its velocity without the intervention of astronomical phenomena. The distance of the stations was 8633^{m}, about 5½ English miles. The number found by M. Fizeau agreed sufficiently with the astronomical result to give the greatest confidence in the exactness of the method, when applied under fair conditions. A new experiment was arranged with Arago in the Paris Observatory, but Arago's death prevented the execution of this design.

Professor Cornu's Researches.—First experiments were made between the Polytechnic School in Paris and Mont Valerein. (Distance, 10310^{m}, about 6½ English miles.)

His researches were conducted with a view to improve the method of the toothed wheel, in order to obtain the greatest exactness. The chief difficulty for the practical application of this method is to measure the angular motion or velocity of the wheel, to which the velocity of light is directly compared. The simplest means would have been, as in M. Fizeau's experiment, to give an uniform motion to the wheel; but such a motion is practically impossible to obtain, so it was necessary to find another mode of measure. The principle of the new improvement was the use of an *electrical registering apparatus*, to register the continuous increase of motion of the wheel. With that arrangement an exact uniform motion is no longer necessary, the observer being able by a peculiar electric signal to point out the instant at which the right velocity is obtained.

The second improvement, and one very important for the exactness of the method, is the substitution of a pair of observations of the return rays, when reduced to a determined feeble intensity, for the single observation of a total extinction.

These improvements, experimentally tried in 1872, gave the velocity of light as 298,000 kilometres per second. The probable error does not rise to 1 per cent.

Professor Cornu's New Determination was made between the Paris Observatory and the tower of Montlhéry. (Distance, 22910^{m}, about 14¼ English miles.)

A direct determination of the velocity of light was ordered at the beginning of 1874 by the Council of the Paris Observatory, on the proposal of M. Le Verrier, Director, and of M. Fizeau, Councillor. The best conditions were chosen for the optical and mechanical apparatus, and the stations were placed at an increased distance. One was erected upon the higher terrace of the Observatory, and supplied with a telescope of 0.38^{m} (1¼ foot) aperture, and 9^{m} (30 feet) focal length. The telescope and the remainder of the

apparatus (toothed wheel, registering cylinder, clocks, &c.) were sheltered under a large cabin constructed on purpose. The opposite station was erected on the top of the tower of Montlhéry; it contains only a reflection telescope sheltered by a cast-iron tube.

The experiments were made in the summer of 1874. The average of 508 pairs of observations gave the velocity as 300,400 *kilometres in a second of mean time.* The probable error appears not to exceed one-thousandth.

Second Solution for Direct Measurement of the Velocity of Light was obtained by the method of the revolving mirror (1850; based on the use of it by Sir Charles Wheatstone in his beautiful researches on the Velocity of Electricity (1834). Arago, after an enthusiastic account of these researches before the Paris Academy, showed how the new apparatus might be adapted to solve some most important problems of optics (1838), and specially to decide between the emission and the undulatory theory of light. He gave (April, 1850) a full description of his own attempts on the subject, but he was not able, through failing eyesight, to fulfill his design. Some days after, the complete solution of the problem was brought before the Academy simultaneously by Foucault and by MM. Fizeau and Bréguet. Foucault, in the year 1865, improved in several points the revolving mirror method, and obtained a direct determination of the velocity of light (298,000 kilometres.)

The principle of the experiment is as follows:

A beam of light reflected on a revolving mirror is normally reflected by a fixed concave mirror, and comes back again on the evolving one: during the time of the propagation of light from the first mirror to the second and back, the revolving mirror has suffered a little angular motion; the new reflection on it produces a small deflection on the return beam; from that deflection the velocity of light can be computed.

This method is certainly one of the most curious, but the deflections are so small and the march of the rays takes place in such extraordinary circumstances that it is difficult to ascertain the degree of approximation of the result.

Physical Importance of the Direct Determination of the Velocity of Light.—The importance of the result is perhaps greater for those physicists who occupy themselves with electricity than for those who work on optics. The beautiful experiments and theories of Prof. Maxwell, Sir William Thomson, &c., so clearly expounded by the British Association Electrical Standard Committee, have shown that the velocity of light is a coefficient common to the undulatory waves, and to the mode of motion which is called electricity. Several determinations, but purely electrical ones, have been made in England of that coefficient, and the results agree as well as possible, in that delicate matter, with the above given value.

Astronomical Importance of the same Determination.—The numbers measuring the phenomena discovered by Rœmer and Bradley, combined with the approached distance of the sun to the earth, have a hundred and fifty years ago furnished an approximate value of the velocity of light. Now the progress of science requires an inverse march; the exact value of the velocity of light permits, by the inverted calculus, the computation of the mean distance of the sun or the sun's parallax, that is to say, the same element which is directly given by the transit of Venus. Professor Cornu's last result, combined with Delambre's equation of light (deduced from more than a thousand observations of eclipses of Jupiter's satellites) or of Bradley's aberration value, which seems one of the best determined number, agree exactly with the result obtained by M. Le Verrier in his researches on planetary perturbations, and with the already known results of the last transit of Venus observations.

THE South Australian Government have contracted with Messrs. W. Simons & Co., Renfrew, for one of their patent hopper dredgers, which will be the largest of that type yet constructed, as it will carry 1,000 tons of its own spoil, and dredge to 30 feet depth of water, and steam out to Australia. This vessel will be built under the direction of Mr. Kinipple, consulting engineer of the harbors of Greenock, and also of the firm of Kinipple & Morries, of Westminster.

THE USES OF FERRO-MANGANESE.

By M. F. GAUTIER, of Paris.

Journal of the Iron and Steel Institute.

The use of specular pig iron, or spigeleisen, as it is termed in Germany, has been a great success in the Bessemer process. For some time after spiegeleisen was first employed, its addition was merely regarded as a re-carbonizing agent, which was rendered necessary on account of the protracted refining—the required hardness was obtained by the admixture of a pure and highly carburetted pig iron, without taking into consideration the part which manganese might play in the operation. Thus steel manufacturers selected their spiegel iron on account of its good and more or less foliated appearance, as this description of pig iron was alone capable of imparting to steel that body which had been eliminated by the protracted blowing. Notwithstanding that there were other pig irons which contained a sufficiency of carbon, it was at length found that manganese was the agent contained in the spiegel, which answered the purpose required.

In 1866, M. Valton, who then conducted the steel works at Terre-Noire, expressed his views relative to the reducing properties of manganese, in the *Bulletin de la Société dé l'Industrie Minerale dé St. Etienne.* He was of opinion that the iron oxyde, with which the Bessemer metal was saturated at the end of the process, was magnetic oxyde, and not peroxyde. He concluded that this was the case, because of the high temperature employed.

The magnetic oxyde, having only the same affinity to silicon as peroxyde, does not come away with the slag, but remains in the pig iron, and thus makes it red-short and unfit for rolling. If, however, we add, in the form of spiegel, metallic manganese—a body which takes up oxygen more readily than iron—the oxyde of iron is converted from the steel bath into a state of protoxyde, and the silicon takes this up to form slag. The reaction is represented by $Mn + Fe^3 O^4 = 3\ Fe\ O + Mn\ O$; and the manganese is also combined with the slag.

Recent improvements in the method of ascertaining the proportion of manganese in iron—a chemical problem which at one time could not be solved—have shown that, in the Bessemer or Siemens-Martin metal, there is always, after the introduction of the spiegel, a small quantity of manganese, which sometimes amounts to half that introduced. Is it to be concluded, therefore, that the manganese remaining in the metal is beneficial—that it forms with the iron an alloy which improves the quality of the steel? Again, is it necessary, in order to introduce sufficient manganese into the metal, that an excess shall be introduced? Recent experience has shown that manganese, without doubt, acts as a reducing agent in the oxyde of iron. M. Bender, the engineer at Krupp's Steel Works, at Essen, has ascertained that 0.35 per cent. of oxygen is sometimes found in Bessemer metal before the introduction of spiegel. It may be taken for granted that the addition of manganese imparts to steel new and useful properties, and when it was discovered that this manganese was the active element of spiegel, it is not surprising that experiments were soon undertaken with a view of condensing it in a special product. The result of the experiments which were practically conducted by Mr. Henderson, of Glasgow, was that ferro-manganese was introduced into the market. The yield of manganese did not exceed 25 per cent., and its characteristic feature was that it was not affected by the magnet. When, in England, the manufacture of the alloy was given up, the Terre-Noire Steel Works Company purchased the patent right from the inventor, perfected the process, raised the yield of manganese to 75 per cent., and reduced the price 50 per cent.

The object of this paper is to consider the principal uses to which this alloy of iron, manganese, and carbon—ferro-manganese by name—is applied.

1st. MANUFACTURE OF SOFT STEEL.

Those manufacturers, who are special-

ly anxious about the quality of their produce, have always used, in the final addition, in the Bessemer or Siemens-Martin process, 1 per cent. of manganese, in the proportion of 10 per cent. of manganese. The spiegel contained 5 per cent. of carbon, and therefore the addition of 1 per cent. of manganese always increased the carbon to 0.5 per cent., and it was difficult, if not impossible, to produce softer steel.

Mr. Henry Bessemer was the first to discover that, in introducing a small quantity of ferro-manganese, sufficient manganese for the reduction could be obtained, and the quantity of carbon would be considerably lessened also. As it is not necessary to melt the ferro-manganese, or to deal with the refuse that is occasioned by the smelting of spiegel, the quantity of manganese added might be less than 1 per cent. if the yield of carbon were diminished, but it is found preferable to have 1 per cent. as the standard. It has been shown that 1 per cent. of manganese in the form of 10 per cent. of spiegel, introduced 0 5 per cent. of carbon into the metal; and 1 per cent. of manganese, in the form of 2 per cent. of ferro-manganese at 50 per cent., will require not more than 0.1 per cent. of carbon to be added. Experiments have shown that the richer the reducing alloy is in manganese the less carbon remains in the produce. Ferro-manganese containing 75 per cent. of manganese is, therefore, the best where the softest cast metal is required.

The following is a comparative statement of the average resistance of steel, manufactured from the same quality of pig iron, but in the first instance spiegel was added, and in the second ferro-manganese:

	With Spiegel.	With Ferro-Manganese.
Limit of elasticity	22 tons per square inch	16 tons per square inch.
Breaking strain	38 tons per square inch	28 tons per square inch.
Elongation per cent. measured over 8 in.	8 tons per square inch	25 tons per square inch.

This decrease of the breaking strain, with the increased elongation, is a decided advantage where hardness of the material is not specially required. The metal, which withstands a heavy breakage load with a small final elongation, has a special elasticity in the shape of resistance to change or form, which is apparent even when it is worked hot. In irregular pieces, this causes tensions, which often induce breakages when cooling, and it was to this unstable equilibrium of the molecule in hard steel, that we must attribute, for the most part, the inapplicability of steel to anything but rails and tyres. It is necessary, when steel is to be used for plates, forgings, machinery, and such like purposes, that it should be very soft, and for these purposes consumers should not require it to stand a heavy breakage strain. In practice, the loads are always supposed to fall with greater or less velocity, and are something similar to a shock. From the construction point of view, the exact value of a material is the product obtained by multiplying the breakage strain by the final stretching, and not the breakage strains alone. These views were long since promulgated by Mr. Mallet, and are well known to English engineers. Applying them to the two kinds of steel named above, and also to common iron, we find:

Hard ordinary steel	305
Soft steel	700
Common iron	105

Experiments made in France recently, have shown that a cannon ball projected against a wall, stayed by soft steel T bars, caused only one-third of the damage that resulted when common T iron stays were used. If hard steel had been employed, the result would not have been the same as when common iron was used. These experiments afforded proof of the superiority of soft material in resisting shocks. Moreover, the limit of the elasticity of soft steel, as compared with that of iron—16 to 9—must be a sufficient guarantee against small imperfections in structure. It is even in the proportion of 9 to 16 that it is advisable in a general way to employ soft steel, when the diminution of dimensions which results therefrom does not cause practical difficulties. A saving in the weight of material, sometimes amounting to 40 per cent., will result, and, in most instances, this will mean decreased expenses, because the price of common iron

and steel, in the future, will not show such a difference as they do now, steel in general being only 25 per cent. dearer than iron. The superiority of soft steel is still more evident, if we consider its use in comparison with that of the best classes of iron, such as those of Low Moor, Bowling, &c. At the Crewe Works, under the direction of Mr. Webb, the advantages of ferro-manganese have been made apparent in the manufacture of certain pieces of machinery, which require great care in their production. The unlimited development of soft steel is only a question of time. The output is now equal to the demand, but as consumers increase their consumption of the material, the production must be increased also. Its use, in the future, will become a necessity, as the substitution of steel for iron rails progresses. In France, and in England, owing to the recommendation of Mr. Barnaby soft steel plates are used in a general way in the Government shipbuilding yards, and the result is that the hulls weigh less, and more room is left for the cargo or the storage of coals.

The best way to adopt in employing ferro-manganese is to bring it to a red heat in order to facilitate the chemical reaction, and to avoid the scintillation which is produced when a cold body comes in contact with the liquid steel. This heating is readily done in the Siemens-Martin process by means of the furnace used for heating the materials of the charge. In the Bessemer process the ferro-manganese may be heated by replacing it—as the weight is less, the alloy being richer—in an iron vessel, suspended in front of the mouth of the converter. When the heating is completed the vessel is emptied into the converter, which is overturned at the same time. The reaction is perfect, and the running of the metal into the moulds mixes the two completely.

Comparing now the use of ferro-manganese with other methods which have been adopted to produce soft steel, it may be stated that the general idea was to restrict to the smallest possible limits the addition of spiegel, so as to lessen at the same time the proportion of carbon. This, however, produced a red-short steel, which was scarcely fit for rolling. In carrying on the Bessemer process, it is found impossible to go beyond a certain point in preventing an excess of iron oxyde in the mass of molten metal. On adding the spiegel, a violent reaction takes place between part of the carbon in the spiegel and the dissolved iron oxyde. The result is an instantaneous production of carbonic oxyde, which often forces part of the contents out of the converter. Of course, the metal is softer, but the process is uncertain, very costly, and dangerous to the men. Lastly, when the pig iron intended for the Bessemer process contains 3 per cent. to 4 per cent. of manganese, a steel fit for rolling is obtained without the final addition of spiegel, and therefore, a soft steel is produced. The oxyde of iron reacts upon all other oxydizable materials —first upon the silicon, then on the carbon, and lastly on the manganese. If, after the expulsion of the silicon and carbon, sufficient manganese is left to reduce to protoxyde all the magnetic iron oxyde which is produced, the metal is not red-short, as protoxyde of iron and protoxyde of manganese combine with the slag. Thus a malleable product, free from carbon, is obtained without the necessity of adding spiegel. This process, however, is both a difficult and uncertain one, for where it is adopted at all, it is necessary, in order not to spoil the manufacture, that the 3 per cent. to 4 per cent. of manganese required shall exist naturally in the pig iron. Where such pig iron is used, great skill is required on the part of the operator, as the spectroscope is not of any use, and the color of the slag is the only guide which can be followed. From time to time the "blow" is stopped, and by means of an iron bar samples of iron are taken out. When the quality of the product is found satisfactory, the process is stopped, but it requires great skill to tell when this point has been reached. Generally the product is not regular, and owing to the high temperature employed it still retains, in spite of its little carbon, a particular crystalline structure, which is found also in Bessemer operations, where the pig iron is saturated with too much silicon. It is certain that in countries like Austria, and the part of Germany where this process is used, soft metal, owing to the nature of the pig iron, is not met with

as a merchantable produce, and has not thus far produced good results. Ferro-manganese is there of great advantage, and to employ it usefully, the manufacturers are doing all they can to lessen the yield of manganese in pig iron. Ferro-manganese, therefore, is more generally being brought into use, as it is found to be the means of obtaining soft steel, and the reduction in the price is assisting in increasing its use, seeing that the employment is rendered more economical and judicious. Another advantage is, that it can be applied as well to the Bessemer as to the Siemens-Martin process.

2d. USE OF INFERIOR MATERIALS IN THE MANUFACTURE OF STEEL.

The most important properties required in metals produced from iron are fusibility, hot forging or rolling, and various degrees of toughness. The chief property of the carbon is to impart fusibility to the iron, but, at the same time, it lessens and sometimes altogether destroys its rolling or forging qualities. Pig iron thus derives its quality of being fusible and not rolling to the great proportion of carbon it contains. When the yield of carbon is decreased, the fusibility is also lessened, but the property of drawing out is increased. Carbon, therefore, destroys the quality of drawing out.

Experience has proved that in producing a smelted metal nearly void of carbon, metal similar to the softest qualities which have been spoken of above, it may contain up to 0.5 per cent. of phosphorus, 0.5 per cent. of sulphur, one per cent. of silicon, and from two to three per cent. of manganese, without losing its drawing out properties. An alloy of silicon and iron without carbon, but with 7½ per cent. silicon, has been perfectly forged. The question may be asked, whether the carbon acts in opposition to these different bodies, or is it the carbon only which exercises the unfavorable effect in the drawing out. Two causes seem to be at work, but it is difficult to explain the phenomenon. Whatever it may be, metallurgists have changed their opinions considerably on this point, and no doubt the future will decide the question, and iron will be presented under a new form to the trade. It is like a productive mine of new alloys suddenly put at the disposal of mankind, which must make its influence felt.

We shall not speak here of the silicon, as it is not found to any great extent in steel, except when it is afterwards purposely introduced. Sulphur and phosphorus, on the other hand, are often found in the production of steel, and it may be taken for granted that the former can be got rid of completely, if the quantity does not exceed the already considerable amount of 1 per cent. This is well known; it is sufficient to work a blast furnace with calcareous slag, and to add, if necessary, oxyde of manganese. The real enemy of the steel manufacturer, that which is met with everywhere, and is found regularly in all the successive operations, in the phosphorus. This is the most serious impurity, and is the most difficult to deal with. Before the effects of the various foreign bodies in steel were generally appreciated, it was taken for granted that with more than 0.05 per cent. of phosphorus, it was impossible to make anything fit for ordinary use with a yield of 0.5 per cent. of carbon, which steel then possessed, it was in fact difficult to exceed that limit without incurring serious losses. The rolling was the insurmountable obstacle as far as the phosphorus was concerned. The difficulty, however, was, to some extent, overcome by hammering the ingots, and undoubtedly this expensive and not very sensible operation (which some antiquated people, principally in Russia, still persist in maintaining in their specifications) has never been of any more use than to facilitate the absorption of somewhat unimportant matters. At present, it may be said that steel for rail making may contain up to 0.5 per cent. of phosphorus, and still be fit for rolling perfectly, that is provided traces only of carbon are contained in it. It has been long known that phosphorus made the rolling of iron easy, whilst phosphorus and carburetted steel could not be rolled.

It must, therefore, be concluded that phosphorus steel, which was not curburetted, would regain this facility for rolling. It was necessary that the question of making soft steel should be solved in a practical and certain manner, and this discovery was, therefore, dependent upon that of ferro-manganese establishing a new use for this alloy. Upon this subject I will now speak.

BENDING TESTS.

BESSEMER STEEL AND PHOSPHORUS STEEL RAILS.

Nord, France, 61 lbs. per yard.
Distance apart of bearings, one metre (3 ft. 3⅜ in.)

AVERAGE OF 25 CHARGES.

Loads in lbs.		Bessemer Steel. Inches.			Phosphorus Steel. Inches.			Description.
27,600	..	0.1	0.0	..	0.09	0.0	..	Bessemer steel.
38,600	..	0.12	0.0	..	0.11	0.0	..	Carbon 0.45 to 0.55.
44,000	..	0.14	0.0	..	0.13	0.0	..	Manganese 0.15 to 0.25.
55,200	..	0.17	0.08	..	0.17	0.04	..	Phosphorus 0.04.
66,500	..	0.32	0.12	..	0.94	0.73	..	Phosphorus steel.
72,500	..	0.64	0.40	..	1.50	1.24	..	Carbon 0.15 to 0.20. Manganese 0.25 to 0.35.
Breaking Weights.		102,000 to 110,000		..	97,000 to 108,000		..	Phosphorus 0.27 to 0.32.

The bending tests show that up to the point of elasticity, phosphorus steel behaves in much the same manner as Bessemer steel of ordinary purity. Further on, the permanent pitch is stronger, the metal gives way more under pressure, and the breakage takes place somewhat sooner than with pure steel. These results are confirmed by the tensile tests made with the same materials, particulars of which are given herewith :

TENSILE STRENGTH.

The Rails are those of the 25 Charges above.	Limits of Elasticity. Tons.		Tons per Square Inch. Breaking Weight. Tons.		Elongation per Cent. Over 8 in.		Over 4 in.
BESSEMER STEEL.							
Samples taken in the head of the rails......	24.7	..	49.7	..	7.0	..	8.5
Samples taken in the flanges................	26.0	..	48.1	..	7.0	..	8.5
Samples rolled into plates..................	23.8	..	45.6	..	9.5	..	11.2
PHOSPHORUS STEEL.							
Samples taken in the head of the rails......	24.2	..	33.2	..	9.5	..	11.2
Samples taken in the flanges................	25.5	..	35.5	..	10.2	..	12.7
Samples rolled into plate	21.3	..	36.5	..	17.7	..	21.3

The rolling into plates ⅜-inch does not much alter the hardness of ordinary steel, but it softens phosphorus steel to a remarkable degree. It is possible that part of the carbon is consumed by this thin rolling, but it is more likely that there is a new fact brought to light—viz., the destruction of the crystalline state of the metal through the alteration and compression of the matter. The fracture which, at the beginning was granular, has a tendency to become foliated. This is a very curious molecular modification, the most important practical result of which is to give to the metal power of resistance to shocks. Starting with an ingot of heavy section, and rolling the rails in two or three lengths, more phosphorus may be admitted without altering its power of resistance ; and, on the contrary, with an equal yield of phosphorus, a greater resistance to shocks is imparted to the rail. This fact has nothing contrary to rule, and has already been proved by the fact that phosphorus iron has been rolled into small bars, and this is well known by the ironmasters of Cleveland and the Moselle department. The resistance of phosphorus rails to shocks varies with the severity of the tests. In France, where the resistance to shocks is measured only by a ram of 300 kilogrammes (662.06 lbs.) falling from a height of two metres (6 ft. 6¾ in.), phosphorus steel stands the tests perfectly well.

Falling (shock) test on the preceding rails, ram of 300 kilogs. (662.06 lbs.) ; anvil, 10 tons ; distance of bearings apart, 1.10 m. (3 ft. 6⅝ in.) ; rails of 61 lbs. per yard.

When the rails have to stand heavier tests, for instance that with the ram of 1,015 kilogrammes (2,240 lbs) the steel requires to be of a somewhat different

composition, and this leads me to consider the influence of manganese on phosphorus steel.

	Bessemer Steel.	Phosphorus Steel.
Heights of fall in feet.	Deflections in inches.	Deflections in inches.
1.5	0.03	0.07
2.5	0.06	0.13
3.	0.14	0.31
5.	0.30	0.47
6.5	0.50	0.91
8.	0.90	1.32
10.	1.30	1.80
Break.	12 to 14 feet.	11 to 12 feet.

We have said that, in the manufacture of soft steel, 1 per cent. of manganese in the form of ferro-manganese of 50 per cent. was sufficient to obtain a suitable quality, and that if richer alloys, say of 60 to 70 per cent. of manganese be used, the proportion of carbon would be still less. When we have to deal with phosphorus qualities, and use 1½ per cent. of manganese with rich alloys of 60 or 75 per cent., there is an excess of manganese, and the metal may retain as much as 1 per cent. of it. The rolling does not seem to be affected; on the contrary, it seems to be rather easier; but what is most remarkable is that phosphorus steel shows a considerable increase in the power of resistance to shocks. The effect of the phosphorus seems to be neutralized by the manganese. I may particularly mention the experiments made at St. Petersburg, for converting light iron rails of English make into steel. These experiments were carried on in the works of the Grande Société de Chemins de fer Russes. What conclusion, from a practical point of view, may be drawn from these properties of soft steel containing from 0.3 to 0.5 of phosphorus? Pure ores are rather scarce, and are likely to become exhausted, and of late years their price has been nearly trebled, owing to the excessive demand. This means, that for common steel rails, for instance, a cheaper means of manufacture is wanted, in addition to an almost unlimited power of production. In the ore process of using a bath of pure pig iron, mixtures may be employed containing 0.3 to 0.4 per cent. of phosphorus. Most English pig iron, except that of Cleveland, is thus treated, and this may lead to a considerable reduction in the cost price. On the other hand, the considerable increase in the use of steel rails consumes a large quantity of old iron rails which have been almost without value. The question of the remanufacture of old materials into steel is sure, in the future, to be brought prominently under the notice of the railway companies. This operation can be performed in the Siemens-Martin process at a cost which compares favorably with that of the Bessemer process.

3d. MANUFACTURE OF MANGANESE STEEL.

Of late years, attempts have been made to apply the term "steel" to certain alloys in which carbon was replaced by sundry simple bodies, such as tungsten, chromium, silicon, boron, manganese, &c. Experience has not shown, however, that such a generalization is warranted. If fusibility, drawing out, and sensitive tempering, are taken as the distinctive qualities of steel, it may be stated that manganese steel exists also. An instance of this may be given in the following analysis:

Carbon	0.38
Manganese	1.38
Iron	98.24
	100.00

This steel is a fine-grained body, whitish gray and very brilliant. Under cold hammering it may be slightly drawn, but cracks at the angles; when red hot, it is as ductile as iron, and is very soft; when white hot it can easily be forged, and can be welded together without artificial means. If it is tempered in water when bright red, the surface scales and becomes as hard as quartz, then it becomes brittle, and the fracture is more brilliant, almost white, and without the bluish glitter. These are, if I mistake not, the properties of a real steel, but notwithstanding a small proportion of carbon, if it were not for the manganese, would place it in the class of soft metals, which cannot be obtained by spiegel. This is, therefore, a new body, which will in the future play a prominent part in metallurgy.

Let us suppose that in the Bessemer or the Siemens-Martin process, and with bodies of ordinary purity, 1½ per cent. of manganese is added by means of ferro-manganese of rich yield, 60 to 75 per cent. for instance. Experience has

shown that only ½ per cent. is necessary for the reduction of the oxyde of iron, and that the metal retains about 1 per cent. of manganese, with not more than 0.2 per cent. of carbon. The following are the results of tensile tests made with four different smeltings of this metal with 1 per cent of manganese:

	Tons per square inch.			
	A. Tons.	B. Tons.	C. Tons.	D. Tons.
Limit of Elasticity	18.4	18.1	18.8	21.7
Load of breakage	35.1	34.6	34.0	37.1
Elongation per cent. over 8 inches	20.0	21.0	20.0	21.77
Elongation per cent. over 4 inches	25.5	25.3	25.0	28.80

This same metal, when at a cherry-red heat, and tempered in water, bears an average breaking weight of 48 to 50 tons per square inch, with an elongation of 4 per cent. measured over a length of eight inches. Its most important characteristic—as may be gleaned by analogy from what has been said above, relative to the phosphorus manganese metal—is its resistance power to shocks. Axles, for instance, have to withstand bending to the extent of five inches, and then to straighten themselves again, the test being made on the centre of the axle, the diameter of which, where the weight falls, is four inches. This, as manufacturers are well aware, is a very severe test, and it is only good metal that can withstand it successfully. It can, however, be said that when 1 per cent. of manganese is added to a steel produced in the manner already described, not only is the test withstood once, but the operation may be repeated several times, and the axle will spring to its original position. Although this metal is not yet well known, that is as far as regards all the uses for which it is applicable, it must be acknowledged that there exists in it a superior quality, which it is easy to give to all steel.

The judicious combination and treatment of the different elements which are at the disposal of man will attract more attention in the future, but only little is known on this question at present. Amongst the elements, which may be most readily used for admixture, is manganese—it is found most plentifully, as a mineral product, and is a most active element.

We must again refer to this influence of manganese because of its utility in the production of steel, and may say that the conclusions arrived at have been come to by reasoning of the most veritable certainty.

In certain cases where manganese is found in small quantities, and is partly eliminated in the successive operations, it may be stated that the perfection of chemical analysis did not admit of the detection of the small proportion of manganese contained in an excess of iron. Manganese is now found in the best steel, where its presence formely was not even suspected. It may now be affirmed that this "steeling" propensity of certain minerals is now available for all districts where they do not exist in a state of nature, under the simple and useful form of ferro-manganese.

THE DECAY OF BUILDING STONES.

By C. P. TOWNSLEY, C. E.

Written for Van Nostrand's Magazine.

In the selection of building materials there are two important requisites, durability and color. Both of these should be combined to make a perfect structure, but the color having only to do with external appearance, is not the point which principally concerns the engineer. He should ascertain the durability, and let color only decide between materials otherwise equal.

In building stone, there are two principal sources of decay, those inherent in the stone itself, and those due to external circumstances. Of those causes inherent in the stone itself, we have first: a want of cohesion among the particles

and porosity, which, in many cases, is a direct consequence of the former. This want of proper cohesion may be due to the absence of a cementing medium, or the stone may not have been exposed to sufficient pressure to consolidate the mass. The result is a weak stone, which, if porous, absorbs much water, and is disintegrated by frost—a most objectionable feature. Too much argillaceous matter is also unfortunate, whether it occurs in seams or distributed through the mass. When in seams we find lines of weakness owing to their better absorbing power. Thus distributed it causes brittleness, and is rapidly acted upon by the weather. Iron pyrites is another, and a most frequent cause of decay. If found in nodules, or in large crystals, its effect is not so disastrous, as when in fine particles distributed through the stone. Ferrodus compounds are also deleterious, as is seen in gray freestone, which is shown by the accompanying table not to be a durable stone.

The effects of iron pyrites seem to be more noticeable among the limestones than any other of the building materials. Prof. James Hall, in his report on "Building Stones to the Capital Commission," says: "If magnesia be present the sulphuric acid formed by the decomposing pyrites produces a soluble efflorescent salt, which exudes to the surface and forms white patches, which are alternately washed off and replaced, but leaving a whitened surface, probably from the presence of sulphate of lime. If the stone be calcareous, the salt formed is insoluble, and therefore produces less obvious results."

The lime from the mortar may produce a similar effect, when the adjacent stone contains pyrites.

The size of the constituent particles or crystals of a stone may affect its durability. This is not always the case, for we find varieties of crystalline marbles which are much superior in strength and durability to those of finer grain. A mixture of fine grains of sand, with pebbles of various sizes, can seldom be relied upon.

The integrity of a stone depends largely upon the character of the cementing material. A clayey medium is not good as it absorbs much water, and is injuriously acted upon by the frost. A calcareous cement is dissolved by rain water, charged with carbonic-dioxyde, while a silicious cement is undoubtedly the most durable, as weathering seems to have little or no effect upon silicates.

The action of frost is first to be considered. This alternate freezing and thawing is, in a climate so changeable as ours, the most trying of any or all other conditions to which a stone is subjected. It is then to this particular point we wish to direct special attention. There are certain general facts by which we may select the durable from the non-durable stones. We know that loose and friable stones, porous, and those with a superabundance of argillaceous matter are severely tried by the action of frost, but there is need of a definite test, and when we consider how very few of our public buildings, erected of stone, have stood for fifty years, we shall be better prepared to appreciate the dilapidation and ruin which must ensue during the next century, and see the great necessity of guarding against its principal cause, the action of frost.

An artificial test for the action of frost has been recommended by M. Brand, a French chemist, which appears to have met with better success than any other method. This consists in procuring a specimen of the stone to be tested of about a two inch cube, then preparing a cold saturated solution of sodic sulphate. Boil the specimen in this solution for thirty minutes, so as to saturate the stone as completely as possible with the salt, then remove the specimen from the fluid, and suspend it in a cool damp cellar over a dish containing some of the solution of the salt, carefully freed from all sediment by filtration. An efflorescence of the sodic sulphate will soon appear upon the stone, when it should be dipped into the solution below, and allowed to remain for some time (until all bubbles of air have disappeared from the surface). The stone is again suspended as before. The process is repeated for a week or more, and the amount of earthy material found in the vessel below will show the action of the sulphate, or the corresponding action of frost. This result, compared with those of similar experiments on other stones, will show the relative action of frost.

The following is a table of some of

the building stones of our own country, with the result I obtained by subjecting them to this artificial test. They were exposed to the alternate action of the solution and air, as above described, for fourteen days :*

	Sp. gr.	Per cent. loss in weight.	Comparative resistance to the action of frost.
Trenton Limestone, N. Y.	2.76	.000286	1.
Onondaga Limestone, N. Y.	2.73	.000363	.7878
Dayton Limestone, Ohio	2.71	.000757	.3778
Blue Limestone, Schenectady, N. Y.	2.55	.000831	.3441
Magnesian Limestone, New Jersey	2.84	.001517	.1884
Granular Limestone, Eastern N. Y.	2.82	.001579	.1811
Columbian Marble, Vt.	2.74	.000404	.7079
Black Italian Marble, Vt.	3.09	.000506	.5652
White Italian Marble, Vt.	2.78	.000522	.5478
Gray Limestone Marble, Salisbury, Ct.	2.97	.000525	.5437
White Marble, Salisbury, Ct.	2.86	.000529	.5406
Irish Marble	2.71	.000625	.4576
Rutland Marble, Vt.	2.71	.000696	.4109
Red Granite	2.65	.000487	.5872
Gray Granite, Barre, Mass.	2.63	.000682	.4193
Gray Granite, Keene, N. H.	2.61	.000873	.3276
Hallowell, Me.	2.64	.000921	.3105
Fox Island, Me.	2.63	.001198	.2389
Black Granite, Haddon, Ct.	2.78	.001203	.2360
Luzerne Gneiss, N. Y.	2.18	.000548	.5218
Gray Gneiss, N. Y.	2.61	.000858	.3333
Syenitic Gneiss, Warren Co., N. Y.	2.53	.001152	.2408
Gneiss from Moreau, Warren Co., N. Y.	2.68	.001523	.1878
Indiana Sandstone	2.48	.000813	.3517
New Jersey Sandstone	2.40	.000911	.3139
Potsdam Sandstone, Malone, N. Y.	2.49	.000953	.3001
Berea, Sandstone, Ohio	2.40	.001132	.2526
Portland Sandstone, Ct.	2.35	.001201	.2373
Basaltic Rock	2.76	.000619	.4620
Semi-metamorphic Rock, near Hoosac	2.96	.001057	.2706
Brick made at Schenectady	1.92	.002168	.1319
Calcareous Tufa, Mumford, N. Y.		.002356	.1214

The Trenton limestone appears to have given the best results (this specimen, however, was much above the average of this kind of stone), next came the Onondaga, while a calcareous tufa of which calcic carbonate forms the greatest amount, gives the poorest results. The specimens of Trenton and Onondaga limestones were of a very close and fine texture, while the tufa was very porous, indeed, nearly as much so as pumice stone. All of the marbles, and all but two of the limestones, gave very good results. The Magnesian limestone was of a very loose structure, and could be crumbled off in grains with the fingers. The granular limestone, though not so loose as the magnesian, was of very much the same character. As there was a flaw in the specimen, the result cannot be relied upon.

The Granites all showed good results. The red granite, which is by experience one of the very best for durability, appeared superior to all others. The Fox Island was not so good, it being coarse grained. The specimen of Indiana sandstone stood the test better than any of the sandstones. It should be remembered that this kind of stone is not uniform in texture, for while in some localities it furnishes a durable stone, in others it is

* These experiments were conducted at the Chemical Laboratory of Union College, Schenectady, N. Y.

quite inferior. The specimen used was above the average.

The limestones which, in the table appear superior to the granites, are not necessarily so, for while the experiment was simply to test the action of frost, there are other agencies which serve to destroy these stones, such as water charged with different solvents. The poor comparison which many of the stones show, should not be taken as showing a stone entirely unfit for building purposes. The calcareous tufa has stood six years in a church at Mumford without apparent signs of decay. It is not, however, a commendable stone.

The destructive action of the frost can be modified by the manner of laying the stone, which should be placed in the building as they were originally in the ground. This is particularly applicable to the sandstones, and our brown freestone is often laid without regard to this law, many of our buildings suffering severely from this neglect.

In and about our cities we have gases given off during the combustion of bituminous coal in particular, which are especially corrosive in their action upon building stones. The granites which have withstood the weathering of centuries in the pure air of the Egyptian deserts, when brought to Paris or London soon lose their sharpness of outline. Limestones and calcareous sandstones suffer more than others, and in the choice of building material, special regard should be paid to the exposure.

The resistance of stone to crushing is a subject of growing interest, and has been thoroughly investigated by Gen. Q. A. Gilmore. The average of ninety specimens of granite, which he has tested, is about 17,500 pounds to the square inch; of forty-three limestones, the average is about 11,000 pounds; of twelve marbles, about 12,000 pounds; of sixty-two specimens of sandstones, it is about 8,500 pounds to the square inch. This gives to the granites a very great difference; still, in some of the most remarkble structures in Europe, limestones are used to support great weights. The pillars supporting the dome of St. Peter's Church at Rome, that of St. Paul's in London, and St. Genevieve in Paris, are all of limestone.

After studying the causes of decay, a means of remedying them must next be considered. There have been many methods recommended for the preservation of stone, and the almost invariable idea has been to render the stone non-absorbent. This has been attempted by combining certain portions of mineral substances, with oil or fatty matters. These, however, all tend to decompose, and when to avoid this difficulty pitchy or bituminous matter is used, the compound is so dark and unsightly as to preclude its use. It is generally conceded that any mechanical mixture not involving a chemical combination must fail. Ransom's process seems to have met with as good success as any other.

THE COMPLETE BESSEMER PROCESS.

From "Iron."

THE session of the Iron and Steel Institute which has just concluded, has indeed hardly been marked by any paper of remarkable interest or novelty. Such exciting questions as mechanical puddling and the details of blast-furnace economy, which have agitated previous meetings so profoundly, have only been lightly touched on. In fact, the meeting would have been inferior to many of its predecessors in technical importance had not its character been redeemed by the animated discussion which, by a felicitous innovation, was introduced by the manager of the Barror Iron and Steel Works giving his experience of the "use of molten iron direct from the blast-furnace for Bessemer purposes." It is hardly too much to say that the result of the conversation thus started is to establish a new point of departure for one of the most valuable processes known to metallurgy.

The history of the origin and develop-

ment of Bessemer's famous invention is, perhaps, one of the most instructive in that curious and generally gloomy record, which tells how great ideas have been, worked out for the benefit of the world by the devotion of men who have rarely reaped the fruit of their labors. The founder of the largest modern steel industry had a peculiar experience, in that, unlike most inventors, he has not only earned but obtained his reward ; and now, just twenty years after the reading of his paper on "The production of malleable iron and steel without fuel," before the incredulous *savants* of the British Association, he is taking part in a series of addresses—for it was hardly a discussion—which establish the superiority of a mode of working which was claimed at Cheltenham, but afterwards abandoned in England till re-introduced from the Continent.

It has been well said that valuable inventions often fall to the ground, simply because the technical knowledge of the day is not up to their level. They are born prematurely into a world which has not the capacity necessary to profit by them, and remain dormant till rediscovered by some one who has not the ill fortune to be in advance of his age. We should otherwise be inclined to say, that the interposition of the cupola furnace between the blast-furnace and the converter, was simply one of that chapter of accidents which attended the first years of the Baxter-House heresy. It appears that when Bessemer began to experiment on the decarburation of cast iron by the injection of air, he did not have access to a blast-furnace, so he was compelled to have recourse to a melting furnace to bring the pig into a molten condition. Whether he would have persevered in his labors if it had not fortunately happened that the first metal be experimented on was good Blaenavon pig, and therefore amenable to atmospheric treatment, seems open to question. But the experiments were successful, and the cupola was associated with the success. Then came the trying period. At Dowlais Mr. Menelaus placed a blast furnace at the inventor's disposal, and direct tapping—or something very like it—was tried. But the pig was bad, and the product worthless. The president of the Institute created much amusement by explaining, with mock indignation, that the inculpated pig was not of normal Dowlais quality, but only tolerated as good enough "for American railway iron." At all events, after this in the subsequent developments of the pneumatic process, the cupola was fallen back on, without any vigorous attempt to make the direct process a success.

It must, however, be recollected that twenty years ago empiricism reigned supreme in the blast-furnace practice of nine ironworks out of ten, and even those which were cautiously calling in the aid of chemical science, had neither the command of ores nor the technical experience, which nowadays render it comparatively easy to produce with regularity any particular quality of pig for which there is a sufficient demand. A uniform quality of pig is essential for the successful working of the Bessemer process ; and the roundabout pig-and-cupola system offered a rough, though expensive, solution of the difficulty, by affording facilities for mixing different brands of pig so as to obtain a pretty constant mean product.

Yet, if we consider the matter in the light of our present knowledge, it certainly seems strange—not to say discreditable—that English metallurgists should have been nearly a generation in adopting a mode of working which was in successful use at Neuberg in Styria in 1865, and in France and Sweden several years ago, and of which, moreover, the *prima facie* advantages are patent. The Bessemer process starts with melted pig-iron ; and melted pig-iron is precisely the substance which is tapped from the blast-furnace. The obvious course would seem to be, either to place the converter close to the blast-furnace and let the molten metal run in direct ; or, if this were inconvenient, to tap a vessel which can be readily discharged into the converter. Common sense revolts against the idea of first running the pig into sand-moulds to cool, and take up an injurious incrustation of sand, and then laboriously removing the cooled pig to be melted again at the cost of expensive fuel. Yet this is what we have, without exception, been doing till quite lately ; and, so recently as the Barrow Meeting of the Institute, there were found able and experienced *steelmasters*, who vehe-

mently ridiculed the idea of its being possible to do otherwise. We will not recall all the arguments that were then used against an innovation which has now the intelligent and candid support of those who then depreciated it, but content ourselves with considering the one point in which it is still contended that the use of remelted pig is advantageous. The heat which maintains the contents of the converter in a state of perfect fluidity, is due to the oxydation of carbon and silicon ; some of the iron and any manganese present also contributing by their oxydation to the total calorific effect. The calorific power of silicon being very high, it depends on the amount of silicon present in the pig, whether the converter charge blows hot forming a perfectly liquid mass—or not. If there be too little silicon present, the blow will be prolonged, and there will be a constant formation of *skulls* ! or solidified metal attaching to the sides of the vessel. If, on the other hand, there be too much silicon present, there will be an excessive loss of iron, as slag ; and there is a difficulty in completely burning out the silicon by the time the carbon is removed. It would appear that from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent. of silicon is an essential constituent of good Bessemer pig, but that a much larger proportion than this is injurious. Here we have the sole valid argument for the retention of the intermediate melting by which the silicon is in part eliminated. But this is only when dealing with very silicious pig, and, by a careful regulation of charges in the blast-furnace, there is no reason why the percentage of silicon should not be kept within such bounds as to render the use of this subsidiary desilicizing process quite unnecessary. In fact, the reverse necessity sometimes arises. In the South of France we find ironmasters driven to discard the remelting system, by the fact that their slightly silicious metal lost so much silicon in the cupola as to render it unfit for the converter. Mr. Snelus, of the West Cumberland Ironworks, finds that, while with the pig-and-cupola process it takes only $23\frac{1}{2}$ cwt. of metal to produce a ton of steel ingots, it requires of the direct-tapped metal about 24 cwt. This half-hundred weight deficiency is ascribed to the presence of too much silicon ; but we can hardly accept this as another than an exceptionally unfavorable case.

As all metallurgical improvements ultimately resolve themselves into questions of comparative cost, it is well to inquire what is likely to be the pecuniary value of the proposed modification of our Bessemer practice. The only estimate given on this point was that of Mr. Snelus, who reckoned the saving at from four to five shillings a ton. Considering that this is at works which were not originally planned for direct working, it may be taken as a safe minimum. Mr. Smith, of Barrow, was less confident as to the saving effected at these monster works, but as, owing to local peculiarities, the molten metal has here to be carried nearly two miles to the converters, it is rather to be wondered at that any success has been attained at all. Indeed, the facility with which it is found that fluid cast iron can be handled and retained in a liquid condition for long periods of time opens quite a new field for technical application. But what is of greatest importance, is the general testimony borne to the superior quality of direct-tapped steel. As quantity is the ideal of blast-furnace managers, quality must always be the first consideration of steelmakers. The immediate effect of these discussions will probably be to render the alliance between iron-smelting and steel-making even closer than it has hitherto been. Those steel-makers who depend on supplies of purchased pig will be placed at a disadvantage, as compared with their rivals who have blast-furnaces on the same ground as their converters, certainly to the extent of some shillings a ton. The result will probably be that all Bessemer pig-makers will gradually become steelmakers as well. At first sight it would appear that, if direct tapping is economical in the Bessemer proeess, it must be equally so in the Siemens-Martin steel furnace. But here we are met by the unexpected fact—vouched for by Mr. Hackney—that the decarburization of a charge of previously melted pig-iron by this system takes quite as long as if the pig were charged in an unmelted state.

The world is indebted to England for Bessemer and Mushet, who invented and rendered available a mode of producing

steel—the most valuable of the metals—on such a scale as to enable it to take the place it deserves among the potent instruments of civilization. But it is only fair we should acknowledge that it is in Sweden and Austria, in France and Belgium, that we have learned that the preliminaries to the actual process may be greatly simplified. We have yet fully to recognize that America has much to teach us in the most advantageous conduct of the process and the construction of a plant, for which they are ready enough to admit they are indebted to British enterprise and ingenuity. But, while our ironmasters continue to show themselves as ready both to learn and to teach as we have seen them during the past week, we need not fear for our iron manufactures.

MANGANESE BRONZE.

From "Engineering."

Mr. P. M. Parsons, well known in connection with the conversion of cast-iron guns into rifled ordnance, as well as for the peculiar metal, which under the name of "white brass" is very largely employed for bearings and other purposes, has recently produced an alloy, which promises to play an important part as a constructive material.

This alloy, called manganese bronze, is formed by incorporating manganese with the various bronze mixtures, with the object of removing any oxyde existing in the metal, by means of the strong affinity of manganese for oxygen. The action of the manganese in the alloy is strikingly visible in the texture of the metal, a fracture of which so far from presenting the coarse granular appearance characteristic of ordinary bronze, is as closely and finely grained as the best qualities of steel, while the strength and tenacity of the alloy is greatly increased, as has been shown by a series of tests lately carried out at the Royal Gun Factory, Woolwich.

Another singular and valuable quality which this metal possesses is the facility with which it may be forged at red heat, these operations greatly increasing its strength and toughness.

The qualities of the metal were tested by six specimens, three of which were cast and the other three forged, the series representing three different degrees of hardness. These samples were proved to ascertain the tensile strength, elastic limits, and ultimate elongation, and the following results were obtained.

1. A cast specimen of tough quality adapted especially for constructive purposes, showed an ultimate strength of 24.3 tons per square inch, with an elastic limit of 14 tons, and an elongation of 8.75 per cent.

2. The same quality forged had an ultimate resistance of 29 tons per square inch, an elastic limit of 12 tons, and an elongation of 31.8 per cent.

3. This was a cast sample of harder quality. It broke under a load of 22.1 tons per square inch, had an elastic limit of 14 tons, and an elongation of 5.5 per cent.

4. The ultimate strength of the same quality when forged, rose to 28.8 tons per inch, the elastic limit was reached at 13.2 tons, and the elongation was 35.3 per cent.

5. This sample was still harder. The cast test piece broke at 23.6 tons, with an elastic limit of 16.8 tons, and an elongation of 3.8 per cent.

6. The same quality forged, had an ultimate strength of 30.3 tons per inch, the elastic limit being reached at 12 tons, and the elongation being 20.75 per cent.

From these truly remarkable results it will be seen that the first sample showed an ultimate strength equal to good wrought iron, while it is greatly superior to the best gun-metal, for which 16 tons per square inch with an elastic limit of 7 tons are extremely high strengths. The effect of forging this metal is also very striking, raising, as it does, the strength to such high limits, and practically giving

a new and most valuable metal to the world. In some respects, indeed, it resembles aluminum bronze, but its resistance greatly exceeds that of this alloy, which does not exceed 22.6 tons per square inch, while its elongation and elasticity are considerably inferior to that of the manganese bronze.

It would be superfluous to indicate the wide field of usefulness in which this metal may be applied. Manganese bronze, by virtue of greater strength and more reliable character, will find an application wherever gun-metal is employed, while the facility with which it can be forged, and the benefit it derives from this operation, will render it still more useful as a constructive material.

HYDRAULIC EXPERIMENTS AT ROORKEE.

By Capt. ALLAN CUNNINGHAM, R. E.

From Professional Papers on Indian Engineering.

The experiments referred to, in the following brief abstract of Capt. Cunningham's report, were conducted during the winter of 1874–5, for the purpose of contributing towards a knowledge of the laws governing the relation between the discharge of rivers and the measured velocities.

As the facilities for such measurement were unusually good, while the skill and care of the experimenter were equally so, the record of the work is certainly a desirable addition to current engineering literature.

We quote directly from the report:

The experiments were performed in the Ganges Canal, which, in the neighborhood of Roorkee, presents unusually favorable opportunities for such experiments in the occurrence of *a straight reach of six miles* of comparatively uniform section, from Dhanourí to Roorkee, the only obstructions in the current above the Soláni Aqueduct being two narrow piers of two bridges at Pírân Kalliar and Mahewa.

This six-mile reach comprises three descriptions of channel, viz.:

i. *Trapezoidal Channel*, in earth, 3 miles long, 150′ average bed width.
ii. *Trapezoidal Channel*, masonry sides (steps), clay bed, 2 miles long, 150′ bed width.
iii. *Rectangular Twin Channels*, in masonry, 932′ long, each 85′ wide.
iv. *Trapezoidal Channel*, same as ii, ½-mile long.

Thus the *same body of water* passes successively through these different channels, each of which is nearly uniform throughout its own length, but differing from each other in material, figure of cross-section, and width—thus presenting a very favorable locality for Hydraulic Experiments.

In order to establish confidence in the Results of these Experiments, it seems advisable to explain in detail the Instruments and mode of observations used for measurement of velocity.

Many instruments have been at various times proposed for this purpose: they may be roughly classed as Fixed Instruments and Free Instruments.

I. Fixed Instruments.—Such are the Tachometer or Current-metre, Pitot's Tube, Hydrometric Pendulum, Water-lever, Water-vane, Hydraulic Balance, Rheometer, &c., &c., which *being fixed in a given position* measure directly or indirectly the current-velocity. Several of these are described in Weisbach's "Mechanics of Engineering," Vol. I., Art. 378, *et seq.*, and in the "Mississippi Report," page 202, *et seq.*

Most of these Instruments—except perhaps "Pitot's Tube" are open to numerous objections. "Pitot's Tube"—as improved by Darcy—has become almost classical from its nearly exclusive use in Darcy and Bazin's Experiments.

The delicacy of observation, however requisite, with all these Instruments—except the Current-metre—necessitates their being used from a very *steady temporary bridge*, the erection of which over a wide channel would of course be impracticable.

Elliott's and other "Current-metres" can be used *from a boat*, but the presence of the boat so greatly modifies the natural motion of the water, that good results could not be expected from them *within a distance of some feet below the boat's keel.*

[Some of the "Fixed Instruments" (*e.g.*, the Current-metre)—in consequence of being provided with a large "tail" which causes them *always to face the current*—measure (or are intended to measure) the actual velocity of the fluid filaments passing them, and not merely "velocity" as defined in Art. 8, viz., the resolved part of the actual velocity parallel to the axis of the stream; but this is on the whole rather a disadvantage (see Art. 8) than an advantage in their use.]

For these reasons, the use of "Fixed Instruments was entirely rejected in these Experiments.

[It may be remarked that for similar reasons they were entirely rejected in the Mississippi Experiments.]

II. Free Instruments, or Floats.—By this term is meant any sort of "floating apparatus," which may for shortness be called a Float, whether floating at the surface, or partly submerged—which is dropped into, and abandoned to the current. In a "uniform stream" all such objects acquire after a time a state of *relative equilibrium* in which their velocity is tolerably uniform. After this "terminal velocity" has been acquired, the Time of passage of the Instrument across the space between two parallel cross-sections at a known distance apart, is carefully timed by one or more chronometers.

It must be observed that the actual Result obtained by this sort of observation is not the "velocity" at a particular point, either of the fluid or even of the "Float" itself—using the term "velocity" in the sense of Art. 8—but is really only the

"Average or mean of the 'velocities' of the 'Float' itself taken over the measured distance, which is expressed mathematically by $\left(\int_0^x v\,dx\right) \div x$," (2),

and it is assumed as nearly certain, that this is *the same as the average of the* "*velocities*" *of a fluid particle* over the same distance.

[For this reason, these "*Floats*" can only be used with any advantage in (so called) "uniform streams." In variable streams, a fixed instrument would be preferable when practicable].

The knowledge of this quantity, although not nearly so valuable as that of the "velocity"—both in direction and magnitude—of the fluid at a particular point would be for the important object of unraveling the laws of motion of fluid, is however almost as valuable for all practical purposes in calculating simply the "Discharge."

These Instruments can be used from a boat, and are therefore the most suitable for use in a very wide channel—except *very close to the edges*, where a "Fixed Instrument" would be preferable (see Art. 35). They were almost exclusively used in the Mississippi Experiments, and have been also *exclusively used in these Experiments.*

With these Instruments the following conditions should be fulfilled:

1°. The whole Instrument in all its dimensions should be so small, as to disturb the natural motion of the water as little as possible.

2°. The dimensions of the parts of the Instrument should nowhere exceed a breadth and depth so small, that the "velocity" of the current is sensibly uniform throughout that breadth and depth.

[In the present experiments, these dimensions were fixed at a maximum of $3'' \times 3''$ for general use, but this *is too large near the edges.*]

3°. The parts of the Instrument should be so arranged, as to severally expose a constant surface (both directly and laterally) to the current, *however the Instrument turns* during the motion—(after the "terminal velocity" has been acquired).

4°. The Instrument should expose as little surface as possible to the wind.

5°. It should be strong enough and simple enough to bear moderately rough handling, and should be convenient to handle.

6°. It should be cheap enough to admit of being made in large numbers.

[In consequence of want of experience as to the best form of Instrument for velocity-measurement in a large Canal, the author decided from the first to use only the simplest and most inexpensive, of such material as could be easily procured, and of such make up as could be readily executed in a small native bazar. This in part led to the sole use of "Free Instruments" (Floats) made of wood.

The experience now gained has pointed out the directions in which more expensive materials and better workmanship may be advantageously employed.]

13. OBJECTIONS TO FLOATS.—As a spirited attack has been made by Mr. Révy (see Révy report *passim*) on the use of Floats, utterly condemning their use at any rate on Great Rivers, and especially for subsurface-velocity measurement, it seems essential to notice it here. Mr. Révy goes so far as to say of the Mississippi Survey—(see page 8 of Révy Report.)

"The Engineeers of that Survey relied entirely on floats, and we consider it a misfortune to science and to practical Engineering that so much ability, perseverance, and time should have been spent to obtain results which the unfortunate choice of floats has inconveniently marred and confused."

This is a pretty decided condemnation of the use of Floats.

Mr. Révy admits, however, (p. 6,) that—"under favorable circumstances the velocity of the surface current may be observed by the movement of a float with considerable accuracy." Suffice it to say, as far as regards Experiments on a straight uniform Canal, the circumstances (which he points out as necessary to use of floats, are highly favorable.)

[Mr. Révy, however, considers a down-stream wind of equal velocity with the surface-current essential to accurate use of Floats. This is quite necessary in the Author's opinion: provided the floats do not project sensibly above the surface (compared with the mass buried below the surface)—a condition easily fulfilled on Canals and small rivers,—they will move sensibly along with the local surface-current, (which is itself of course affected by the wind). A calm or a simple up or down-stream wind would not affect the accuracy of the observations. A cross-wind would undoubtedly interfere seriously with the use of floats; but so it would with useful work with any form of Instrument].

Mr. Révy's principal objections are however to the use of Subsurface Floats.

Nevertheless the use of these Floats enabled the Mississippi Experimenters to clearly establish (page 225—262 of Mississippi Report).

1°. That the line of maximum velocity is generally below the surface.

2°. That its position depends on the wind.

[A law of dependence was even proposed.]

Now both these Results are fully verified by the present Experiments conducted solely with Floats, and Result 1° is also fully borne out by the Darcy-Bazin Experiments, performed solely with a different instrument (a Pitot's Tube).

It can be verified at once by any one for himself by simply throwing a chip of wood and a common beer-bottle filled with water enough to sink it pretty deeply into a current together, when the bottle will be found as a rule to move the quicker. It has also been long known to watermen that a deeply laden barge floats more quickly down-stream than a lightly laden one.

Result No. 1° (above) may be said to be one of the best established Results of modern Hydraulic Science.

The Instrument used by Mr. Révy—a Current-metre—in preference to the Floats, which he condemns, *did not enable him to recognize this so easily established fact at all.* He declares (p. 87), relying on his own Experiments with the Current-Metre, that the maximum velocity line is at the Surface, and argues (p. 87), that it *ought to be so.* The inference would seem to be that this Instrument (Current-metre) is not so delicate an Instrument for velocity-measurement as the (condemned) Floats.

Suffice it to say here, that the objections (though serious enough) are—in the author's opinion after this season's experience—by no means so insuperable (at any rate as applied to Canals not exceeding 9 feet in depth) as Mr. Révy considers. These objections would be undoubtedly aggravated at greater depths.

But is the Current-metre proposed by

Mr. Rêvy *more trustworthy* than the Sub-surface Floats? Comparative Experiments alone could decide this. Mr. Rêvy gives none.

Omitting the detailed account of the experiments, we give herewith the writer's summary of results:

For facility of reference a summary of the results of this paper are here collected: the results are not arranged in the order in which they occur in the text, but in that which seemed most convenient for exhibiting the results at one view:

The term Velocity in Hydraulics means usually only the Resolved part of the Actual Velocity parallel to the axis of the current; for mere discharge-measurement this is a more useful quantity than the actual Velocity.

Fixed Instruments are—in consequence of the delicacy of observation required—in general (the "Current Metre" excepted) suitable only to positions where a steady support can be secured; *i. e.*, only to small streams, and to observations close to margin in large streams.

Free Instruments are alone suited in general to large streams.

Free Instruments do not measure the Velocity at a point but only the Average Velocity (the term Velocity being taken as above defined) along the stream-line throughout their run: for mere discharge-measurement this is quite as useful a quantity as the resolved part of the actual Velocity at a point would be.

No "Free Instrument" yet invented for measurement of subsurface-velocity in a large stream is quite satisfactory.

The conditions which should be fulfilled by an Instrument of "direct observation" are essentially inconsistent, and can therefore be only partially satisfied together.

Instruments of "indirect observation" labor under the disadvantage of depending on some hypothesis of law of fluid pressure. Most "Fixed Instruments" have this disadvantage.

Of the four subsurface-instruments tried, and as constructed for these experiments:

The "Single Ball" fulfills all conditions except—(the most important for an instrument of "direct observation")—that its surface-float is not small enough for the effect of surface-action on it to be fairly negligible.

The "Tin" fulfills that condition in the highest possible degree, but fails in not exposing a constant surface directly and laterally to the current, and in not retaining itself at a constant known depth.

The "Twin Balls" depend for their utility on a hardly certain theory, and the observational requirements of that theory are very difficult to fulfill: they are, therefore, liable to more irregularity than the "Single Ball."

Wood is to hygroscopic to be a really suitable material for these instruments for delicate observations: metal would be preferable.

The "Single Ball" made in metal would probable be as good a subsurface "Free Instrument" as could be desired.

The "Rod" is not well suited for experiments to investigate laws of fluid motion,

and is useless as an Instrument of precision for measurement of mean velocity of a vertical plane;

but the discrepancy between the velocity of a rod and the mean velocity through its length is not so great as to interfere seriously with its practical use for discharge measurement.

The motion of a large body of water is unsteady, (even in a uniform channel of great length), *i. e.*, the velocity at a point varies considerably from instant to instant.

Single Velocity measurements are therefore incomparable unless simultaneous, a condition generally impracticable.

The Average Velocity at a point taken through a long interval of time, is sensibly constant under similar external conditions (of wind, depth, &c.)

Average-Velocity measurements derived from very numerous observations are therefore alone comparable, and not single measurements.

Hydraulic experiments in general must therefore necessarily be very tedious and consequently very expensive.

Comparative experiments with different instruments are therefore also very tedious.

Horizontal Velocity-Curves and Vertical Velocity-Curves depending on single

Velocity measurements are very irregular.

But the areas of the Surface Velocity-Curve and Mid-channel Vertical Velocity-Curve (computed from many ordinates *i. e.*, velocities measured—not simultaneously—but in succession) are approximately constant.

There is a probability, therefore, that the (superficial) discharges across the surface, and in the mid-channel Vertical plane are approximately constant.

The Surface-Velocity Mean Curve is strikingly regular and is symmetrical about mid-channel in a symmetric uniform channel of great length.

Its form depends on the figure of the cross-section.

In a very wide channel (breadth not $< 9 \times$ depth), it is a very flat curve.

In a rectangular section in masonry with a depth $= \frac{9}{85}$ of breadth it is approximately a "quartic ellipse" whose equation is

$$\frac{u^4}{u_0^{\,4}}+\frac{y^4}{b^4}=1$$

The Surface-discharge in same case

$= .927 \times$ Central Surface-Velocity $\times$ Surface breadth.

The Surface-Velocity near the margin decreases very rapidly with proximity to the margin, and at the margin itself is extremely small, perhaps zero in case of straight margins of great length.

There is a constant surface motion from the margin towards the centre, most intense at the margin.

The Average Central Surface-Velocity varies at same place on a calm day nearly as the square root of the central depth, or as the square root of the hydraulic mean depth.

The Mid-channel Vertical-Velocity Mean Curve is strikingly regular, and is approximately a common parabola, whose equation is

$$(z-Z)^2 = p\,(V-v)$$

whose Axis is usually below the surface at a depth (Z) depending on the state of the wind,

and whose parameter increases very rapidly with the depth.

The Mid-channel Mid-depth Velocity is variable from instant to instant,

but the average of the same through a long time exceeds the Mid-channel Vertical Plane Mean Velocity (U) by a very small fraction; and is, therefore, convenient as a practical measure of that Mean Velocity.

The form of the Curve is hardly well enough determined (to be a *common* parabola) to admit of the Bottom Velocity being thence inferred.

The line of maximum Velocity of a Vertical Plane is highest at Mid-channel, and is more and more deep-seated further from Mid-channel.

The Velocity of a "Rod" is variable from instant to instant but its average velocity over a long time is sensibly constant.

Mean Velocity curves depending on single mean Velocity-measurements are irregular.

But their area is nearly constant, showing that the (cubic) discharge is nearly constant.

The Mean Velocity Mean Curve is very regular, and very much flatter than the Surface-Velocity Mean Curve.

The Mean Velocity of a rectangular section, $85' \times 9'$ in masonry, computed from Mean Velocity-measurements with (Rods) does not differ from the Mean Velocity of the Darcy-Bazin Results more than the probable observation-errors.

The present experiments lasting only four months, are of course only a small contribution to Experimental Hydraulics. It is to be hoped that they will be only the beginning of an extensive series of experiments in India, prolonged over several years under varied conditions on a large scale.

The Text will have shown numerous points on which further experiment is very desirable. But some limitation seems urgently required to prevent experiments being too diffuse, so as to secure some practically useful result within a reasonable time.

It might seem for instance desirable for the advancement of Hydraulic Science to aim at the discovery of the

"Figure and Size of the 'Velocity-Surface' for the most 'useful cross-sections in masonry and earth in a "uniform Channel of great length,"

giving thereby the "velocity" (u) at any point of a cross-section as a function of

(*a*), the central surface velocity (u_0),
(*b*), the co-ordinates (y, z) of the point,
(*c*), the several dimensions (b, H, &c.,) of the cross-section.

So that in fact, f being now a known function

$$u = f(u_0, y, z, b, H, \&c.)$$

from which the Discharge would be at once calculable by reduction of the expression,

$$D = \iint u\,dy\,dz,$$

which might be done in a form suited to practical men once for all.

Nevertheless, it appears to the Author —after the experience of this season— that the above result could not be looked for within any reasonable Expenditure of time and money, unless some very much more expeditious mode of ascertaining the Average Velocity along a "stream line" can be discovered then by the use of Floats, as in these experiments.

[Thus it appears from Art. 33, that about a fortnight's work is necessary for the discovery of the Figure and Size of a single "Horizontal Velocity Mean Curve," so that the establishment of the Figure and Size of the whole "Velocity-Surface" would necessarily take many weeks, during which the canal must be maintained *of uniform depth of flow* at the chosen section].

This will be understood to be the consequence of the motion of water not being technically Steady, but only an Average Steady Motion.

[The important consequences of this were of course only gradually realized in the course of these experiments.

The following seems to the Author the best course for future experiments in order, to realize some practically useful results with a reasonable expenditure of time and money, viz.:

1° "To verify whether the Mean Velocity past any vertical whatever is approximately the same as the mid-depth 'velocity' on that vertical."

2°. "To verify whether a 'Rod' sunk to nearly full depth measures approximately the Mean Velocity of its plane of motion, in any vertical plane whatever."

At present these two facts can only be said to have been verified (by the Mississippi Experiments, and by the present Experiments) *for the mid-channel plane.*

If either 1° or 2° can be verified *for all vertical planes* (as well as the Mid-channel plane), practically useful Results could be comparatively rapidly developed. Thus experiments would then be directed to ascertaining the

"Figure and Size of the Mean Velocity Mean Curve for the most useful Cross-sections in masonry and earth in a uniform channel of great length,"

giving thereby the Mean Velocity (U) *on any vertical line* as a function of

(*a*), the mid-channel Mean Velocity (U_0).
(*b*), the abscissæ (y) of the line.
(*c*), the several dimensions (b, H, &c.) of the cross-section.

Besides which, Experiments would be required towards determining the

Mid-channel Mean Velocity (U_0) as a function of the central Surface-Velocity (u_0) and of the several dimensions (b, H, &c.) of the cross-section.

So that in fact f, Φ being then known functions,

$$U = f(U_0, y, b, H, \&c. \ldots\ldots\ldots),$$
$$U_0 = \Phi(u_0, H, \&c.)$$

From which U would be calculable in terms of the known dimensions (b, H, &c.) of the cross-section, and of a *single* (the central) surface-velocity (u_0) to be obtained *by actual observation.*

Such a Mean Curve could (it is believed) be generally determined *for any one central depth* with sufficient accuracy in about a fortnight's work, provided the canal could be kept running steadily at one level throughout that time.

For *each foot of central depth*, the Mean-Velocity Mean Curve should be separately determined.

This would complete the really necessary Experiments at one section.

An American manufactory has made 180,000 rifles for the Prussian Government, and is making 145,000 more.

THE BEHAVIOR OF METALS UNDER REPEATED STRAINS.

By LUDWIG SPANGENBERG, Professor der Königl. Gewerbe Akademie Zu Berlin.

Translated for VAN NOSTRAND'S ENGINEERING MAGAZINE.

II.

The fracture of iron extended only to the neutral axis, so that the compression-side had to be sawed apart. Above the neutral plane, on each vertical section, appeared a shell-like depression. From the fact that the compression-side bore the strain for a longer time than the tension-side, we infer that the absolute strength of wrought iron is less than its resilient resistance; contrary to the statements in most of the books. It does not occur to the writers that it is possible that, under repeated bending towards one side, the resilience of the compression side as well as its tenacity may gradually increase. The rupture of steel takes place through the entire section, apparently by tension, while the neutral plane is generally higher. This is due to the brittleness of the metal. But sometimes there appears on the upper edge a plane inclined 45° to the other rupture planes, which obviously has been caused by compression. A similar result appears in the axle steel, tested by falling weights; the section being perpendicular to the convex side, and forking at three-fourths the height, so that the piece forced out is in the shape of an equilateral triangle.

Phosphorbronze resembles steel in fracture; common bronze is like iron.

In the case of two steel rods under torsion, the rupture plane was divided into two entirely different parts by a chord perpendicular to the radius drawn to that point of fracture which was the centre of radiation. This is always on the tension-side in bent rods, so that it may be inferred that the rupture of axles under torsion is also due to tension, and not to compression. In iron rods under torsion, there are sometimes found two or more such chords and several centers. The rupture-surface is sometimes fibrous, sometimes globular. The fact that the smooth surfaces near the center of fracture are in general larger in proportion to the number of strains before rupture, *i. e.* in inverse ratio to the maximum tension; and the other fact that the center of fracture always lies on the tension-side, lead to this conclusion: that in consequence of repeated tensions the crystalline surfaces (joints) gradually become amorphous, so that several conditions of molecular equilibrium ensue; each corresponding to a limit of elasticity; that afterwards by continuance of the tensions the final limit is passed, and the resistance of the section is diminished so much that the force of the dynanometer is sufficient for rupture.

This hypothesis accounts for the appearance of the surfaces of rupture; *e. g.* for this; that the parts furthest from the centre of rupture have the same shining and crystalline look as rods broken by a suddenly applied strain. And this hypothesis is intimately connected with the "molecular constitution" of bodies, a theory now held by most physicists, and which is opposed to the old doctrine of the "homogeneity of masses."

The following principles appear in several works, especially in Moll's *Reine und Angew. Elem. Mechanik*, (Braunschweig, 1854); and in Redtenbacher's *Dymanidensystem* (Mannheim, 1857).

I. Molecular forces, attractive and repulsive, act in all bodies. The vehicles of these forces are atoms. Atoms are corporeal or ethereal, and exist simultaneously in every body.

(*a.*) The corporeal atoms of the body are inert and heavy, and mutually attract one another.

(*b.*) Corporeal and ethereal atoms mutually attract one another.

(*c.*) Ether atoms are inert, but not heavy (massive), and are so small in comparison with the corporeal atoms, and with the ethereal interspaces, that their form need not be regarded. The action between them is repulsive.

II. Among atoms the following forces operate:

(1.) *Universal gravitation; i. e.* the intensity of attraction between two corporeal atoms varies as the product of

their masses directly, and inversely as the square of their distance from each other; and is independent of their material constitution.

(2.) *Physical attraction.* By this is meant that force by virtue of which the same pair of corporeal atoms attract each other with a force varying directly as the product of their masses, and which diminishes very rapidly as the atoms are separated.

(3.) Chemical attraction, or affinity, by virtue of which two heterogeneous corporeal atoms attract each other.

(4.) *Ethereal forces.* Between ether atoms repulsion takes place; but between ether atoms and corporeal atoms there is attraction, varying directly as the product of the masses, and in a rapidly diminishing ratio of the distances.

III. Because of repulsion the weightless atoms of ether expand throughout space, penetrating all bodies, but concentrate more or less about corporeal atoms because of their attraction. Assuming that the distance between corporeal atoms is very great compared with their magnitude; and that the intensity of attraction between corporeal and ethereal atoms is very great compared with the repulsion between ether atoms; and that the number of ether atoms in a given volume is indefinitely greater than the number of corporeal: it is obvious that the ether will be disposed atmospherically about the corporeal atoms, and that each atmosphere will be of definite form and limit, so that a large part of the space between two corporeal atoms will be utterly void. It would also follow that the density of the ethereal envelop would decrease outward from the atom. Such an atom with its envelop is called a *Dynamid.*

IV. A molecule is a balanced group of two or more dissimilar corporeal atoms having a common ether envelop. As two distinct atoms can form a molecule A, so two like or unlike molecules may unite to form a compound molecule B.

V. Redtenbacher conjectures that the radial oscillations of ether atoms, which cause expansion of the envelop and increase of repulsion are connected with the phenomena of heat, while their continuous rotatory motion corresponds to the electric current.

The proposition of III, regarding the void spaces between atoms, we cannot reconcile with the hypothesis that ether fills entire space. We rather adopt Cauchy's view; that the intervening space is entirely filled with ether. This, Redtenbacher thinks, is the case only with solid substances, in which the corporeal atoms attract the ether atoms but feebly.

We shall now attempt to establish our hypothesis heretofore stated, by the application of these principles, and by the results of our experiments.

It is known that most, if not all, of the important technic metals show a tendency to crystallize when cooled from a melted to a solid condition (especially if the cooling be rapid). The atoms group about axes of symmetry, if unhindered. Otherwise a crystalline joint is formed. For example, if melted metal is poured into a cylindric vessel, made of a material which is a good conductor of heat, so that the metal near the outside cools rapidly, while that within remains fluid; then if the interior molten portion is drawn off at the bottom, it is found that the metallic shell left behind shows crystalline forms upon its surface. This tendency to crystallize extends throughout the entire mass when it is cooled.

This may be regarded as the first normal condition,* in which there is equilibrium between the attractive forces of the several groups of atoms, and the repulsive forces in the ether envelopes.

If the body has the temperature of the surrounding air, the radial ether vibrations of both are of equal intensity, and the velocities are equal. Every change of temperature, therefore, causes a destruction of the internal equilibrium, and a consequent wave-motion of the groups, causing decomposition into atoms or molecules, with a consequent change of volume, which, if maintained, corresponds to a new normal state. If besides temperature, mechanical forces are acting, such as compression or tension, the wave-motions or disturbances of the groups are either suppressed or hindered; hence the new normal state depends upon the qualitative or quantitative operation of the external forces.

* Two molecules may be so situated that their molecular forces are in equilibrium. Such a condition, due to internal forces only, is called a *normal state.*

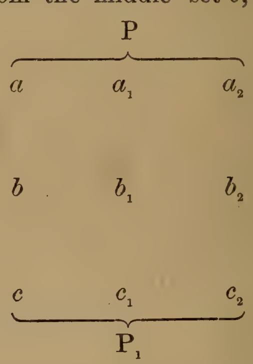
Cast iron, bronze and brass, are generally in the first normal state when taken from the foundry, but not so wrought iron and steel. The latter metals run through a series of normal states under the hammer and roller before they are ready for use.

Experience shows that in the case of iron, which contains only a small per centage of coal, hammering and rolling while hot, when the atoms are in oscillation and the groups are for the most part decomposed, causes a distribution which produces a fibrous grain. This may be explained as follows: The motion of the ether is diminished, or turned in other directions by the hammer or the roller, so that groupings of atoms take place; these groups are brought nearer each other by the working of the metal, until the ether envelopes by virtue of their force of repulsion prevent a further approach of the groups. Suppose the direction of the pressure of two rollers to be vertical, then the vertical dimensions are diminished and the horizontal increased, so that the atom-groups of some of the vertical series are displaced, and push the groups of other series in such directions that no external forces oppose them; and as a consequence new series are formed, so that, for example, groups which were at the corners of cubes assume a pyramidal form.

The square form of a perpendicular section is changed to a lozenge, then to a rectangle. Now, if a body of the last form is broken by slow bending, the horizontal laminæ separate from one another, because the ether in the vertical series is compressed, and the upper horizontal series are stretched. As this extension is not uniform the rupture section has a fibrous grain. Perhaps, large crystals have been resolved into smaller, and these, working in between the larger, give a fibrous look. But if the rod is broken by a sudden blow, the rupture has a crystalline aspect, because the rupture is due to shearing, and the longitudinal fibres have not had time to become extended.

So it is with steel; with the qualification that the form of the molecules and the distribution of groups is different.

It is not possible that working and rolling can force the atoms or molecules of a crystalline group into actual contact; since, in that case the repulsive force of the ether must be done away with, and the attraction of the atoms would become infinite, so that the decomposition of a crystal would be impossible. Hence, we may assume that in every group in the condition under consideration, there is a very dense ether atmosphere, which, when aided by external forces, causes a subdivision into smaller crystals, and then a reduction of these into atoms or molecules brought into close contact, so as to produce an amorphous condition. This decomposition is helped along by the mutual attractions of the exterior atoms of two adjacent crystals, and hindered by the intervening ether. Suppose two opposed bands of external parallel forces uniformly distributed through a very thin plane section, whose resultants are P and P_1, then the external forces will draw away the crystals a, a_1, a_2, and c, c_1, c_2,* from the middle set b, b_1, b_2, be-



cause the repulsive forces of the ether envelopes is aided by the external forces. The squares change into rectangles, and a motion of the easily disturbed ether is induced. It becomes denser in the horizontal intervals $a\,a_1$, $b\,b_1$, &c., than in the vertical, $a\,b$, $b\,c$, &c., so that there is a flow from the latter to the former. But at the same time a radial motion of the ether takes place from a to b and back again; hence the heat phenomena observed by Wohler in cases of great strain. Electric and magnetic phenomena may also occur, since there must be rotatory motion of the ether on account of the greater density about the horizontal diameter of the crystal. In the

* For the easier comprehension of this, let a, b, c, etc., represent cubic crystals, each separable into 8 equal cubes.

first stage the equilibrium of the ether external to the crystal takes place, diminishing density in a horizontal direction so that the attraction of the crystal is less hindered, and the vertical elements $a\ b\ c$, $a_1\ b_1\ c_1$, etc., approach one another diminishing the transverse dimensions in the second stage.

The envelops within the crystal are induced by their repulsive force to take part in the equilibrating movement of the external ether; but are hindered by the attractions of the crystal molecules or atoms, and can therefore express their force only by operating upon the atoms or molecules of the crystal, thereby setting in motion those parts which are applied to adjacent crystals, since these suffer a less pressure on the opposite side. In this way a disintegration is effected of crystals of the first into the second, third, etc., in order so that in the third stage the material is uniformly distributed. These three stages are included in the short interval of time of a single stress within the limits of elasticity. If the forces P and P_1 cease to act, then the original condition recurs: but in our experiments the strains occur in rapid succession, and, only those displaced atoms or molecules which are in close proximity can reunite into crystals of the second or third order. Here we discover the reason that not only the number but the time of duration of stresses has an influence upon rupture.

Perhaps it is not certain that crystalline structure changes to amorphous with every stress, especially with the first; for rods broken after a few strains show a crystalline rupture. But that regular forms become smaller and that the amorphous condition increases, is shown by the smooth mirror-like elliptical spots on the broken surfaces of different kinds of steel. The molten-like spots in iron are to the same effect.

A new normal state occurs at each diminution of crystals, corresponding to a new kind of elasticity; so that instead of a single limit there is a series. But with each change of limit the strength of resistance increases; and the raising of the limit by working and loading is proven by many experiments.

Moll says: "The more crystalline the structure of a body, the less its resistance. The rupture of such bodies is due to the separation of the small crystal groups, not to the breaking up of single crystals. The cohesion of the molecules that form a crystal is greater than that of crystals with one another. The strength of a body increases as its structure approaches the amorphous state when its atoms have a homogeneous distribution."

Though the truth of this statement has been shown by experiment, it will be instructive to investigate the causes. Consider a vertical column of crystals a, b, c, etc, each of mass m; which may be regarded as concentrated at its centre of gravity. Let e, be the common distance between the centers of gravity; and K an unknown co-efficient, then the attraction of b by a, is

$$A_1 = K\,\frac{m^2}{e^2}$$

Suppose each crystal divided into two equal crystals, *e.g.*, a into a' and a'', b into b' and b'', &c., and suppose a' remains in the place of a; that a'' is displaced through one-half of the space $a\,b$, so as to be distant $\frac{1}{2}e$ from a''; then a'' is attracted by a' with the force

$$A_{\frac{1}{2}} = K\,\frac{m^2}{4} \div \frac{e^2}{4};$$

obtained by putting $\frac{1}{2}m$ for m and $\frac{1}{2}e$ for e in the above equation. Of course $A_{\frac{1}{2}} = A_1$; hence the attraction of two adjacent groups has not increased according to the law of gravitation. Taking four groups, a, b, c, d, we have the following results:

b by a, attractive force, $K\dfrac{m^2}{e^2}$

c by a, attractive force, $K\dfrac{m^2}{4e^2}$

d by a, attractive force, $K\dfrac{m^2}{9e^2}$

$$\text{Total, } S_1 = K\frac{m^2}{e^2}\left(1 + \frac{1}{4} + \frac{1}{9}\right)$$

Suppose these groups broken up into crystals of half the size a', a''; $b'\ b''$, we then have:

a'' by a', attr'tive force, $K\dfrac{1/4\,m^2}{1/4\,e^2} = K\dfrac{m^2}{e^2}$

b' by a', attr'tive force, $K\dfrac{1/4\,m^2}{e^2} = K\dfrac{m^2}{4\,e^2}$

b'' by a', attr'tive force, $K\frac{1/4\,m^2}{9/4\,e^2}=K\frac{m^2}{9\,e^2}$

c' by a', attr'tive force, $K\frac{1/4\,m^2}{16/4\,e^2}=K\frac{m^2}{16\,e^2}$

c'' by a', attr'tive force, $K\frac{1/4\,m^2}{25/4\,e^2}=K\frac{m^2}{25\,e^2}$

d' by a'. attr'tive force, $K\frac{1/4\,m^2}{36/4\,e^2}=K\frac{m^2}{36\,e^2}$

d'' by a', attr'tive force, $K\frac{1/4\,m^2}{49/4\,e^2}=K\frac{m^2}{49\,e^2}$

hence $S_2=K\frac{m^2}{e^2}\,[1 + 1/4 + 1/9 + 1/16 + 1/25 + 1/36 + 1/49]$

We find $S_2 > S_1$; and as a, b, c, d are subjected to the same attractive force S_1, while a' is attracted by a'', b' by b'', &c., with the force S_2, it follows that the cohesion of a' with the vertical fibre is greater than that of a. But whatever holds true of one fibre, holds for the sum of all the vertical fibres of a rod; and we may infer that the tensile resistance of a rod increases along with the disintegration of the primitive crystals up to the amorphous condition. This increased resistance might be weakened again if the repulsive force of the ether increased in the same ratio. But the ether envelops of the new crystals become less dense because of the diminished mass of the latter; and the ether in the body is spread throughout a larger space, since the specific gravity of a body diminishes as the volume is increased.

The disintegration of crystals of the first order may also be due to continuous load, when sufficiently small increments of load are added at regular intervals. As soon as resolution of crystals of the first order into the second is effected, permanent extension results; that is, the first limit of elasticity is reached. But as long as only a few crystals have parted from the mother-crystal and are lying in close proximity, it is possible that these may be restored with the removal of the strain, or when it has been reduced to a very small amount. If the crystals of the second order have been changed to the third the second elastic limit is reached, and between this and the first limit the metal is as elastic as before. This explains the raising of the elastic limit under increasing tension.

Knutt Styffe, Director of the Institute of Technology at Stockholm, defines the limit of elasticity as follows: "If a rod of steel or iron is stretched by continual increase of load, at first so small as to cause no sensible permanent extension, then is gradually increased, and allowed to act for a number of minutes depending on the ratio of the increase of weight to that of the whole rod: then the elastic limit is the weight which produces a permanent extension amounting to about the ratio of the increase of weight to the entire load. Let P represent the total load; dP the constant increment of load; L the length of the rod; dL the increase of permanent extension due to $P+dP$, if this acts for $100\frac{dP}{P}$ minutes: then the elastic limit corresponds to the weight for which $\frac{dL}{L}$ is approximately equal to $0{,}01\frac{dP}{P}$. That is, $100\frac{dL}{L}\cdot\frac{P}{dP}=1$ or nearly 1."

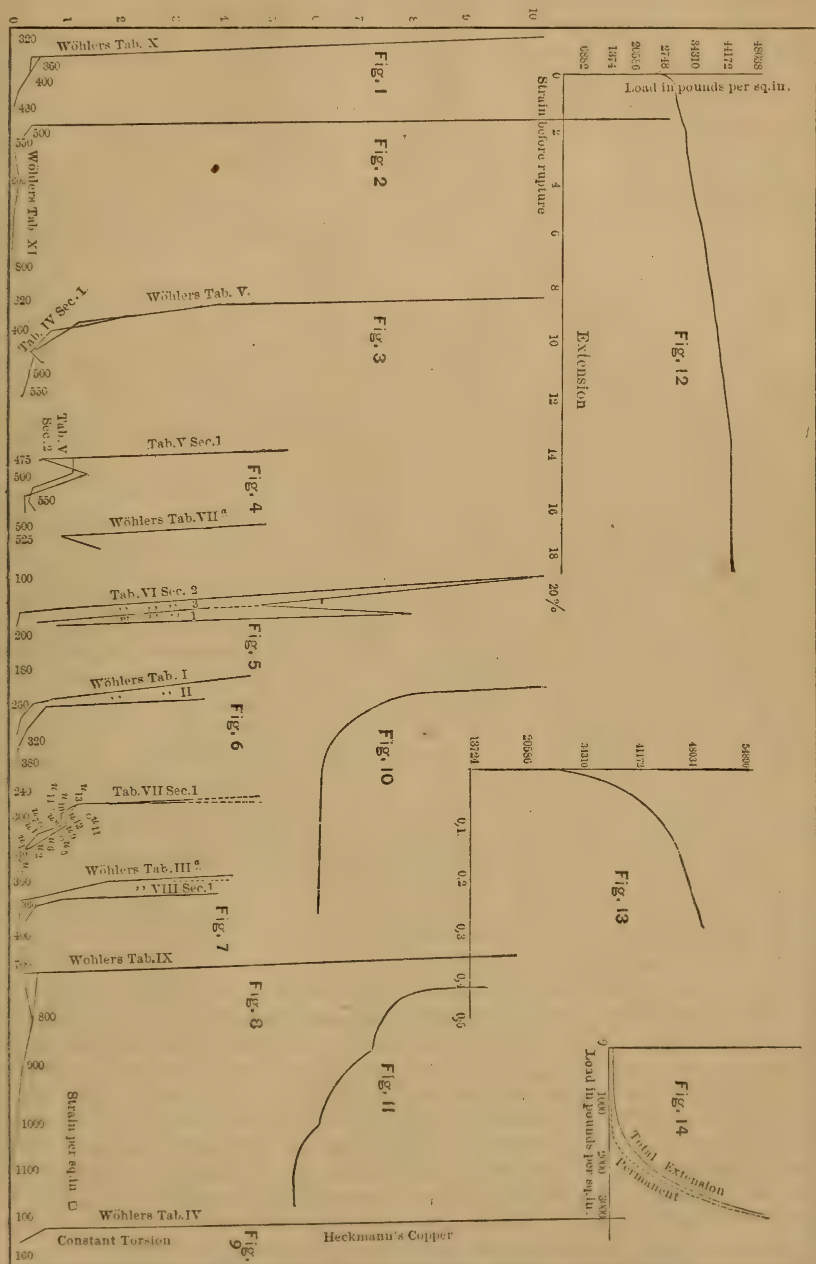
With this definition as datum, Styffe determines in an arbitrary way one of the many elastic limits which lie between the first normal and the final amorphous state.

Styffe gives several curves as examples in which the applied weights are laid off as ordinates, and the per cents. of extension, as abscissæ. One of these curves is represented in Fig. 12. Observe the several elevations of the curve (in which there is au appearance of periodicity) which may correspond to what we have called the several normal conditions. Fig. 13 is the beginning of Fig. 12 to a larger scale: the elastic limit lies near the point where the curve has the smallest radius of curvature. These curves have some similarity to the curves 3, 5 and 6; and possibly some relations, not yet made obvious.

Moll & Reuleaux maintain that the elastic limit may be changed by a change in the normal states; but that in the case of some metals, as wrought-iron for example, its magnitude is slightly affected.

Wohler also found in experiments in bending that the elastic deflection depends not upon the increase of the total deflection, but upon the total load alone. He concludes that

permanent and elastic change of form cannot depend upon the same physical property. This opinion we share with him, for this and other reasons. According to our hypothesis permanent extension is associated with disintegration of



mother-crystals caused by the ether-repulsion. The diminution of transverse dimensions, when a rod is lengthened, is proportionally smaller than the elongation, since under extension the specific gravity diminishes.

Elastic extension is due to the fact that the equilibrium between the attract-

ive forces of the nuclei and the repulsive forces in the envelops is disturbed by the external attractive forces with loss to the former; the disturbance disappearing at the same time with the cessation of the action of external force. Perhaps we may say that the elastic extension depends upon the momentary suppression of the general attraction of the masses (excluding physical and chemical forces); and that it remains constant with equal increments of the strain, because the mass of the rod remains constant.

Fig. 14, shows that the limitation of elastic phenomena to certain metals is a necessary conclusion. The ordinates of the full curve show the total extension in English inches of a bar of phosphor-bronze; the abscissæ correspond to the loads in English pounds; the ordinates of the broken curve represent the permanent extensions. The differences of the ordinates correspond to the elastic extensions which increase from 0, to 22000 lbs., then decrease to 33916 lbs, when rupture took place. Perhaps it happened that after the breaking up of the compound molecules, groups of copper, tin or phosphorus formed, and the groups of the last-named flowed among the other groups so as to prevent the approach of the first two kinds.

The above explanations seem to contradict the well-known phenomenon that extensions generally increase more rapidly as the load approaches the breaking weight. We think that this is true only up to the beginning of the amorphous condition due to repeated or increased load. A body is then perfectly elastic, only so far as this term applies to bodies not absolutely homogeneous. While each increase of load induces a separation of the crystals such that the sectional area does not diminish just as the length increases, no increase of volume can be caused by increase of external forces after the uniform juxtaposition of the atoms. The next addition of tension, if not too great, may cause only a lengthening parallel to its own direction and a contraction of cross-dimensions. But the molecules of the cross-section are brought together as closely as if pressures from without were acting. Hence molecules may be forced out of the cross-rows to form new rows; or new groups are formed, so that the section is permanently diminished: for if tension breaks up groups then pressure must tend to construct them.

Together with the permanent diminution of the section there occurs a permanent increase of length and *vice versa.* Hence results formation and dissolution of groups, with a rapidity proportional to the increase of the force of tension. Finally there comes a load so effective that the groups have not time to break up, and rupture takes place by means of shearing.

Indicate the breaking load per square unit of original section by P_b; this strain, in case of repeated tensions, does not correspond to unlimited duration; but possibly to the smaller value P_a, which is in equilibrium with the amorphous condition. But this can hardly be granted, since P_a as soon as brought into action would cause sudden and various changes of crystals, so as to cause an amorphous condition in some fibres, not in others; so that shearing would be induced and rupture would follow. This view is supported by the fact that iron rods which had borne repeated tensions, when broken by pull were found to be bent, though before rupture they were quite straight. This could not be charged to the excentric application and working of the tension, since in most cases the curvature was opposite in direction to that which might be due to transverse operation of the machine.

It may be shown that the strain corresponding to an unlimited number of tensile strains is $u = \frac{1}{n} P_a$. Since the time of change to the amorphous condition (and therefore n) cannot be determined in the ordinary experiments, it is best to determine u, or the working resistance a by Wohler's method. Wohler's question: "Is there any limit of tension which is perfectly safe?" cannot be answered in the affirmative, since that strain must be sufficient to produce the amorphic condition directly and must not be great enough to form crystals in the cross-section by pressure. The use of iron for girders in buildings need not be rejected; yet it is worth while to consider what may be the effect of the vibrations produced by the continual passing of vehicles.

It hardly needs mention, in order to reconcile an apparent discrepancy in the experiments of Styffe and Sandberg, that if the strain P_b is applied, rupture must take place by sudden shearing, because the groups have not time to break up and pass over to the elastic limits of new normal states.

The results of the experiments of the former on extensions between $-37.7°$ and $200°$ C. were : (1.) The absolute strength of steel and iron is not diminished by cold ; being at least as great at the lowest temperature in Sweden as at the ordinary. (2.) The extensibility of steel and iron is not less at very low temperatures than at ordinary. The fact that car rails and axles break more readily in cold weather, Styffe attributes to the circumstance that the road-bed is less elastic, so that shocks are more intense.

In order to test this explanation, Sandberg, who translated Styffe's work into English, made experiments on steel, the results of which he published in the appendix to his translation. He assumed that the elasticity of granite does not vary between the limits of a hot summer and a cold winter day. He had a granite rock smoothed and leveled and placed upon it two cubical blocks of granite to serve as supports for the rails to be tested. Each rail was divided into two halves ; one of which was tested in summer at $+29°$ C.; the other, in winter, at $-12°$ C., by dropping upon them a sphere weighing nearly nine centners. The sections of ten bars showed that at the lower temperature iron had but one-third or one-fourth of the resistance which it had at the higher; also that the tenacity and resistance to bending were notably affected by cold.

Regarding these results as trustworthy, we explain them as follows : The radial motion of ether which appears in the form of heat, after some time causes the same disintegration of crystals as repeated or increased strains. But cold, like compression, which is attended with less vibration, promotes the formation of groups; these diminish tensile resistance, and make the material brittle on account of its crystalline structure. Sandberg subjected the rails, which had become crystalline under the influence of cold, to a sudden blow ; of course they broke more readily in winter than in the summer. On the other hand, Styffe broke his rods with a hydraulic machine ; increasing the strain gradually, so that he gradually broke up the connection of the crystals, thus substituting mechanical work for ethereal vibrations.

As fibers are not homogeneous in their structure, they must contain a varying number of crystals. Those fibers in which the crystals are not so dense, are more strained by tension so that the groups are quickly broken up. Forced by the ether they leave the molecular groups of fuller fibers and seek the fiber most strained in order to restore equilibrium. Hence the ray-like appearance of the fracture-surfaces of steel and phosphor bronze. The fibers nearest the weakest fiber are more extended, and are successively brought beyond the amorphous condition so as to have less tenacity. The effective section of resistance becomes gradually smaller; and at last the dynanometer breaks the remaining crystalline section, which therefore has an appearance as if sawed or broken with the hammer.

That bars of square section break at the corners is explained by supposing that the flow of molecules to those parts is less free than to others. In the broken steel rods there appeared on the upper edge a small plane (wedge) inclined 45°, having the appearance of being pushed out. This is the angle of maximum shearing effect.

Crushing proper cannot be produced by pressure when it causes approach of molecules and formation of crystals. Separation can be caused only by shearing, or by "nicking," or by the increase of sectional area, from the ends toward the middle, causing a deficiency of molecules at the edge. The last may be the reason of the sudden fracture of bars subjected to alternating tension and compression. Wohler says : "Pieces bearing positive and negative strains must be made stronger in the ratio 9 : 5 than those strained only in one direction." The explanation of this is not easy. Launhardt's is not sufficient, for he considers the case in which the limits of elasticity are passed on both sides. Wohler's hypothesis that the difference of strains suffices for rupture, and that in the case of alternating tension and

compression this algebraic difference is the sum of the numerical values of the strains, is also insufficient.

A *B* *C*

A *B* *D*

A C_1 *B* *C*

It is probable that if a fibre A B is stretched longer by the amount BC, there is less molecular change than if stretched by a length B D longer than B C; but in our opinion it does not follow that B C + B C′ produces the same change as B D, if C C′ = B D. We should rather believe that if the elongation B C were somehow suppressed, the fibre would return to its normal condition, and that the shortening B C′ could not be more injurious than if it occurred in the normal state without previous elongation. The only satisfactory explanation seems to be involved in the theory of Moll and Reuleaux that, for the same normal state, there are two co-existent limits of elasticity, one for tension, the other for compression.

If the elastic limit of tension is raised by repeated strain, *i. e.*, if attraction is increased and repulsion diminished, then the elastic limit of compression is diminished. Hence, if the elongation B C due to tension lies within the elastic limit, the equal compression B C′ causes a permanent shortening, and after some time a rupture. But it is also possible that compression causes a bending toward one side or an elongation of sets of fibers near the periphery, so that a new normal state results in that part, which reduces the section of resistance. The case of a rod under repeated torsion is not relevant to a decision of this question, because each fiber is alternately convex and concave. Other experiments must be made with new machines adapted to changing axial or transversal positive strain into negative. We may then ascertain what is the effect of a greater strain of one kind following a less of the other. We think it will be found that our assumption is not far wrong, that a slight compression following tension is rather advantageous than the contrary.

Wohler's observation that between + 440 and + 240 Ctr., and between + 300 and 0 vibrations may occur with equal safety, requires the confirmation of further experiment.

In consequence of the construction of the machines for bending and pull the dynanometer must first give a strain of 240 Ctr. in the outermost fibres; then the extreme strain of 440 Ctr. is applied; hence a normal state must result different from and higher than that which would follow the tension zero. It may be asked what would be the normal state if the strain 440 were first applied, and then the strain 240. Perhaps the result would be the same as if the force P_b spoken of above should act. The answer may have a practical bearing with reference to bridge building. The weight proper of structure corresponds to the lower limit 240 Ctr., and if the rolling load increases the strain by 200 Ctr. the total permissible strain is reached. Suppose the weight of structure uniformly distributed, then the vertical component is a maximum at the ends and zero in the middle, and the tension members at the abutments are in better condition to bear external forces than those in the middle, on account of the raising of the limit of elasticity. The former may therefore for a total load of 440 Ctr. have "indefinite duration," because they may rise from 240 to 440 Ctr. tension; but not so of the latter, since they pass from 0 to 440 Ctr. strain; 300 being the limit. Assuming 110 Ctr. as the permissible strain, we should have 4-fold security at the abutments, but less than 3-fold in the middle.

We shall now attempt to account for the appearence of the surfaces of fracture of rods broken by repeated torsion. In the case of steel rods the circular section-surface was divided into two unequal segments; one of which, that next the side of initial fracture, and the smaller, was close grained and smooth; the other being coarse-grained and somewhat crystalline in appearance. This seems to contradict the statement above made that rupture takes place only on the tension side and that the adjacent surfaces pass over to the amorphous condition; for each fibre of these rods was pulled during half a rotation and compressed during the other half. The process may be as follows:

If the rupture at a is the consequence of tension, the bending of the rod, since the most efficient fibre has ceased to resist, will be greater than if it had turned through an angle α bringing a to a_1 or to a_2 (the neutral section) while an unbroken fibre is brought to the top. In its further progress to a_3 or from a_4 to a_5 the broken fibre induces no greater

FIG. 6.

bending since the broken parts support each other. Indeed it is possible that the bending is less during the last half rotation than during the first. If before fracture there has been a permanent extension of the fibre a and the adjacent fibres, the rod is permanently bent downward. After a half rotation it would be bent upwards, were it not for the fact that the stress of the dynamometer acts downward. But in no case is the upper fibre so much bent as it would be if the elastic limit of the lower fibres had been passed.

It would now seem to be clear that if the fibre a is at the top, the adjacent fibres reach the maximum stress, causing the amorphous condition of the upper segment. Upon the side opposite a the crystals are larger than they are near the chord of division, showing a higher state of disintegration.

Appearances similar to those of steel are observed in iron, but they are not so sharply defined.

If the equilibrium of the ether and the consequent amorphizing is in any way hindered, there may be other segments of rupture.

The rupture of iron and steel under torsion shows a smooth surface adjacent to the fracture, while that of bronze is shining, and phosphor-bronze is often dark-brown or blackish on the opposite side. This may be explained by supposing that after the breaking up of crystals into molecules, these partly resolve into atoms, those of tin gathering at one place, those of copper and phosphorus at another.

We must reject the theory that iron is made crystalline by repeated tension, since bending and tension appear, by our experiments, to break up the crystalline structure; while compression promotes it. So the upper parts of rails become crystalline and hard because subjected to compression. Whether irregular shocks promote crystallization remains to be determined by experiment.

The rupture-sections generally show in what way breaking has occurred; whether by repeated strains or by the sudden shock of a great load. This may be of import in discovering the cause of an accident, as, for example, whether it is due to a broken axle or a broken rail. This might be determined by an examination of the peculiarities of the sections of fracture.

There remains to consider the possible effect of heat in impairing strength by vibration of the molecules. Heat separates the crystals, causing change of position in all directions: and when it is uniformly distributed, if the amorphous state occurs, the strains in cross-section are exactly equal to those in longitudinal, so that there is either diminution of section, or re-grouping only, which is not competent to effect rupture as long as the aggregate state is unchanged.

We have had Krupp's axle steel hardened and then broken; the grain was much closer and smoother than in the same not hardened. But if steel is first heated and then hardened the rupture-surface becomes more like that of the non-hardened, according to the duration of the heating; while the grain of steel heated and not hardened is coarse and globular. So is that of heated iron. Hence it would seem that red-heat produces no tendency to form groups, while a higher heat, long continued, induces a storm of ether atoms, so that in cooling, they gather in irregular groups; a phenomenon observed in cast metal.

The experiments of Styffe mentioned above, which show that the absolute resistance of steel and iron at high tem-

peratures, up to 200° C., does not diminish, while that of soft iron increases, contradict Muller, in the Zeitschr. des Ost., Ing. u. Arch. ver. (1873) where he says: "When a bridge-member, in the course of twenty-four hours, suffers a lowering of temperature to the amount of 15° C., there is a change of its length amounting to 0,00022. The elastic change of length is the same up to a load of one-third the limit. So a change of temperature has the same effect as a load."

Finally, we refer to the diagrams. In all the polygons there is a point from which the ordinates increase very rapid-idly. This may be compared with that one in Styffe's curve, Fig. 13, which corresponds to the shortest radius of curvature, in the vicinity of which lies the limit of elasticity. We may conjecture that the abscissa corresponding to this point, *i. e.*, the load, answers to some important condition of the metal, possibly to that in which the irregular crystalline structure becomes more regular. It may be that, up to this point, the number of strains necessary for rupture depends upon the specific nature of the rod, while it afterwards depends upon the general properties of the metal. Hence it may happen that irregularities of the polygons are more frequent before this point is reached. That non-homogeneous metals may be improved by repeated strains is not impossible. Suppose, for example, there is a thin section of slag running across a rod. This may be broken up into several parts by small tensions, which may be disposed by the motion of the ether into a direction parallel to the tension, so that the decomposition of crystals is less hindered. The attraction of homogeneous molecules to both sides of the section may be diminished, but not destroyed; and there may be an equilibrium between the force of attraction and the repulsive force of the ether increased by the action of external forces. A greater external force would break the rod at this section.

The less obvious this point in the polygon the more homogeneous and pure the metal. This appears in Fig. 9. And, from Fig. 7 it may be inferred that Krupp's steel is now much more uniform and stronger than that of 1862.

Time and space forbid further presentation of facts supporting our hypothesis. It is to be hoped that others will pursue the subject further.

The following corrections should be made in the first portion of this article in the last number:

Page 450, last line, read 45,000,000.

Page 452, 2d line from bottom, 2d col. read "to have much greater strength than."

Page 459, 22d line from bottom, 2d col., read "occurred after 10 million."

Page 459, 4th from bottom, 2d col., read 800 instead of 500.

Page 460, second from top, 1st col. read 480 instead of 450, and 350 instead of 300.

Page 460, 9th from top, 400 Ctr. instead of 900 Ctr.

COHESION AND CRUSHING.

From "The Engineer."

The resistance which a body offers to strain, whether tensile or compressive, is clearly due to the cohesion of its particles; that is, to the force which sticks or binds them together. The proper mode of ascertaining the behavior of a body under strain would therefore be to deduce it from the laws of cohesion. Unfortunately, of these laws we at present know nothing. There is no domain of science in which so little progress seems to be made as in this. Whilst we know with the utmost exactness how it is that the earth is held in its constant orbit round the sun, we are completely ignorant of the forces which hold in one mass the stone which lies at our foot. It has been said that no future philosopher can ever hope to rival the fame of Newton, because the law which governs the universe can be discovered but once. But the laws of cohesion hold just as widely, and perhaps are of even greater practical importance. There is ample

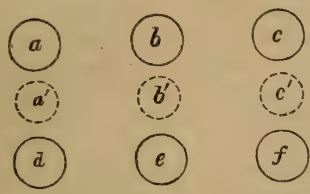
room for a second Newton to take rank with the first by proclaiming their discovery, and when a second Newton arises, perhaps the discovery may be made. Meanwhile, all we can do is to feel our way by the light of such principles as, in the general darkness of the subject, we can still manage to discern. Let us consider what are the elementary facts which may be observed when a body (for instance, a bar of iron) is subjected to longitudinal strain. Of these the most obvious is that the body alters its dimensions, becoming longer if the strain is tensile, shorter if the strain is compressive. In other words, the particles of the body follow the direction of the strain, becoming further apart if it tends to separate them (tensile strain), and nearer together if it tends to unite them (compressive strain). The particles oppose a powerful resistance to this motion in both cases, and it is this resistance which, gradually increasing until it equals the external strain, brings the body once more to rest. Now, this resistance must be due to a force of repulsion existing when the particles are urged towards each other, and a force of attraction existing when they are drawn apart. It follows then that the force of cohesion acting between these two particles must be twofold, consisting of an attraction and a repulsion. These must alike be insensible at any except very small distances, so small as to be quite beyond all ordinary modes of measurement. This is evident from the fact that two bodies when placed in contact do not cohere, nor can they in general be made to do so by pressure, however powerful. The only explanation of this is that, owing to the roughness of the surfaces, the number of particles brought sufficiently close to act upon one another is exceedingly small, and therefore the resistance they oppose to separation is but trifling. Cases are however recorded in which surfaces of metal have been brought to so high a degree of polish as to cohere together with considerable force. This is generally attributed to the pressure of the atmosphere, the surfaces being supposed to be so smooth that no air can find its way in between them. This is in itself sufficiently improbable, whilst it must be remembered that this external pressure would oppose no resistance to the sliding of the surfaces over each other, but only to their being drawn directly apart. There would thus be no real adhesion in the ordinary sense of the word. It would seem much more likely that in these cases the inequalities of the surfaces have been so far planed down that the forces of cohesion do to some extent come into play. Be this as it may, the fact remains that these forces only act at distances, not infinitely, but immeasurably small. It is not meant by this that the forces absolutely cease to exist at greater distances. This would not be impossible, but would involve complicated laws of force which it is not necessary to assume. The conditions are satisfied by supposing that they vary inversely according to some power of the distance. This is actually the case with regard to one force which is known to act between particles, namely, the force which we call gravity. The law of gravity is expressed by saying that every particle in the universe attracts every other particle with a force varying inversely as the square of the distance between them. In other words, if we represent by 1 the amount of the force at a distance of 1 in., then at 2 in. it will be represented by $\frac{1}{4}$, at 3 in. by $\frac{1}{9}$, and so on. It is evident how rapid is the degradation of force under such a condition. As a matter of fact, we know that the attraction between two bodies, even when in contact, is quite inappreciable. Even the enormous mass of the earth only exercises on a body at its surface that moderate force to which we give the name of weight. But if we suppose two particles whose distance apart is immeasurably small, the case is quite different. The force would then become considerable; and, in fact, if we could imagine the two particles in actual contact, the attraction would become infinite, or no finite force would be able to separate them. It would seem, then, that gravity is exactly the kind of attractive force whose existence we have been proving from the phenomena of cohesion. Hence, as we know that gravity exists, it seems just to assume that this cohesive force of attraction is nothing else than gravity acting at small distances. With it, as shown above, must be combined a repulsive force of similar

character. This repulsive force is greater than the attractive within the distance of equilibrium, as is shown by the fact that force is necessary to produce compression; but beyond that distance it falls rapidly below the attractive force, so that in the motions of the heavenly bodies no trace of it is visible. This will be accounted for most simply by supposing the force to vary inversely according to some power of the distance greater than the square. On this supposition the algebraical expression for the two forces together would be $\frac{k}{d^2}-\frac{k^1}{d^m}$ where d is the distance, $k\,k^1$ are constants, and m in some quantity greater than 2.

Of course, this expression is only to be accepted as an hypothesis; nor is it offered as fully representing the apparently complicated forces which produce the phenomena of cohesion. As far, however, as the results due to strain are concerned, it seems sufficient to answer our purpose. It follows that, in considering the effects of strain on any particle of a body, all the other particles except those immediately adjacent may be left out of consideration. In fact, the particle may be considered as occupying the center of an exceedingly small solid sphere, the constituent particles of which exert upon it a force of attraction or repulsion according to their respective distances. It is thus that the forces of cohesion have been looked at by a French engineer, M. Pelletieau, in a paper published in the *Annales des Ponts et Chaussees* for July, 1873. From thence he draws several conclusions with respect to the behavior of materials under a compressive or crushing strain, which, if true, are of great importance, but which appear to the writer to be open to considerable criticism.

It may be well in the first instance to state what these practical rules or conclusions are. They apply to a prism of any material, standing upon a plane base and crushed by weights placed upon it. They are as follows, all other things being supposed in each case to be equal:—(1) The resistance to crushing is greater, as the friction between the prism and the plane is greater; and is greatest when the prism is absolutely fixed to the plane; (2) the resistance to crushing is greater as the base is more flexible, or in other words, yields to a greater extent under the load; (3) the strongest form that can be given to the prism is that of a circle; of polygonal forms that which approaches nearest to the circle, or has the largest angles, will be the strongest; (4) the crushing strain will be greater proportionally for a small prism than for a large one; (5) the crushing strain will be greater as the height is less. Before discussing these rules we must explain what is here meant by the crushing of the prism. There are several ways in which bodies may yield under compressive strain. In Rankine's *Applied Mechanics*, art. 285, there are enumerated five, viz.: (1) Crushing by splitting into prismatic fragments; (2) crushing by shearing, or sliding of one portion upon another along oblique surfaces of separation; (3) crushing by bulging or lateral swelling and spreading of the prism, which is the usual form with ductile materials, such as wrought iron; (4) crushing by buckling or crippling, as in wood and other fibrous materials: (5) crushing by cross-breaking, which happens with very long pillars only. It will be observed that these are all what may be termed indirect methods of yielding. There can, in fact, be no such thing as direct crushing of a body, analogous to its breaking under a tensile strain. The pressing together of two particles can only produce an increased resistance due to their mutual repulsion; and even an infinite compressive force could do no more than bring them into actual contact. In fact the breaking of a body, whether by crushing or tearing, can only be due to separation, not compression of its parts; and this is in fact what happens in all the five cases enumerated above. Of these, the second and fifth are due to peculiar causes; but the other three are clearly modifications of the same result, namely, the splitting or tearing apart laterally of the prism under the distension produced by the compressive strain. The fact of this distension or lateral spreading of the body under compression is certain, and may be shown by experiments on any highly elastic substance. Thus, if a short block of india-rubber, be squeezed between the finger and thumb it will be seen to thicken out most perceptibly, at the same time that it short-

ens under the pressure. The cause of this lateral thickening is not so obvious ; but, in fact, it may be seen to follow from the principles of cohesion explained above, and thus affords an additional verification of those principles. Thus, let us imagine a body composed of six particles only, *a*, *b*, *c*, *d*, *e*, *f*, which are



in equilibrium under their respective attractions and repulsions. Now, suppose a compressive force to act upon the body, and to bring the particles *a*, *b*, *c*, into the position a^1, b^1, c^1. Let us then consider what will happen to the particle *d*, and whether it will have any tendency to move laterally, this is, along the line *d e f*. As the particle was originally at rest, the forces tending to move it along this line must have been in equilibrium. These forces were repulsions due to those of the adjacent particles which were within the distance of equilibrium (or that at which the forces of attraction and repulsion are equal) and attractions due to those which were beyond it. Let us suppose the forces to have been in fact a repulsion due to the particle *e*, and attractions due to the particles *b*, *c*, *f*. The particle *a* will of course exercise no effect in the lateral direction. Now, when the compression has taken place it is evident that the distance of *d* from *b*, *c* (in their new positions b^1 c^1) has diminished. Consequently, the attraction of those particles has diminished also, for this attraction is zero at the distance of equilibrium, and increases thenceforward (the attraction here spoken of being, in fact, the difference between the force of attraction and the force of repulsion at that particular distance). But while the attraction of *b c* has diminished, the forces due to *e f* remain the same ; hence, as there was equilibrium before, there will now be an unbalanced force of repulsion due to *e*, and therefore the particle *d* will move in the direction *e d* until, by the increase of distance, this unbalanced repulsion is diminished to zero. By exactly similar reasoning it may be shown that *f* will move along the line *e f*, and that *a c* will also move outwards ; *b e* will alone retain their positions, being balanced by the forces on either side of them. It seems clear that similar effects will be produced where the number of particles is very great, as in ordinary cases, and thus the distention or spreading outwards of a body under compression is satisfactorily accounted for. The contraction of area under tensile strain, which is so familiar a feature in experiments upon extension, may of course be accounted for on precisely similar principles. It is not, however, so easy to see how this distension of the body under compressive strain can ever result in fracture, as the repulsive forces to which it is due continually diminish in intensity as the distance between the particles increases. In fact, it seems probable that in a perfectly homogeneous body no disruption would ever take place, and it would squeeze out under the pressure as an inelastic substance does. But as a matter of fact, no bodies are perfectly homogeneous. There always exist in them weak points, which we may conceive as *lacunæ* or crevices, partly bridged over by particles hanging in suspense, as it were, between the attractions of the two walls. Now, if an unequal pressure be brought upon the two sides of this crevice, thus modifying in the way described above the attractions which they exercise, this state of suspense will cease to exist ; the intervening particles will move towards one side or the other, and may, if the difference of attraction be sufficiently great, break off permanently from the further and attach themselves to the nearer. Thus, a disruption may begin which will soon propagate itself through the mass. As the general motion produced is outwards, it seems clear that any force acting inwards, or tending to keep the particles of the body together, will counteract the effect of the pressure and increase the resistance of the body. And if there is any line within the cross section of the body along which this inward force is exceptionally weak, then it is along this line that a disruption of the kind described will first take place.

It is thus that the problem of resistance to crushing appears to have present-

ed itself to M. Pelletieau, although he has not given any general view of the subject such as has been sketched out above. The lateral splitting of the prism by distension is what he understands by the word crushing; and his investigation of the most important point—namely, the proper shape of the prism—depends on the last principle laid down, namely, that crushing will first occur along the line in which the inward force, tending to hold the prism together laterally, is least. Such an inward force he shows to be produced by the attraction excited on the particles at the surface. Thus, let M, Fig. 1, be any

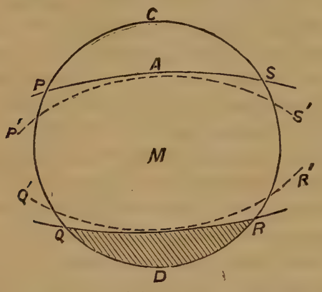


FIG. 1.

particle of a body, and describe round it a circle P Q R S with the "radius of action," that is, the radius beyond which the effect of cohesion may be considered insignificant. Then, if we suppose M to lie in the interior of the body, all the particles within this circle will indeed act upon M, but their respective actions will balance each other, and M will have no tendency to move in one direction more than in another. The case is different if we suppose M to lie so near the surface of the body that this surface comes within the distance of the radius of action. Thus, suppose the circle P Q R S to be normal to this surface, and to cut it in the curve P A Q S. Suppose Q B R to be a line on the other side of M, opposite to and exactly similar to P A S, then it is evident that the particles within the space enclosed by the lines P A S, Q B R, will be symmetrical about M, and the forces they exert will be in equilibrium. But the particles in the space Q B R D will be unbalanced, as the opposite space P A S C is outside the surface. Thus, if we suppose P A S C to have existed originally and to be suddenly cut away, then Q B R D will at once exercise an unbalanced attraction upon M, which will therefore move towards it until it is checked by the repulsion of the particles between M and the line Q B R. The nearer M is to the surface the larger this space Q B R will be, and therefore the more powerful the force with which M tends to move towards the interior of the body. The general effect is, that the outside layer of a body always acts strongly to compress the interior, and may be compared to an elastic envelope tightly strained over it and squeezing it together. It thus resists the distension which is caused by compressive strains, and which according to the views expressed above, produces the crushing of the body. Granting this, will the amount of this resistance vary according to the shape of the cross section, so that with some bodies crushing will take place earlier than with others of the same substance and area but of different form? M. Pelletieau answers this in the affirmative: The principle he affirms is, that crushing will begin at the point of the outline of the cross section at which the radius of curvature is least. Thus, the circle is the strongest form of section, since any other curved figure of equal area must have a smaller radius of curvature at some point. Similarly a curved section will always be stronger than an angular one. M. Pelletieau deduces this result from the consideration of Fig. 2, in which M M' are two particles

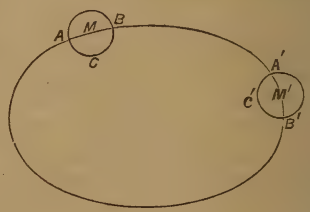


FIG. 2.

situated at the edge of an oval figure, and A C B, A' C' B' are the circles of action drawn round them. Now at M, where the radius of curvature is greater, it is clear that the part A C B of the circle of action falling within the figure is greater. Hence M. Pelletieau concludes that the attraction which this part exercises on the particle will be greater owing to the increase of area,

and therefore the resistance to crushing which that attraction produces will be greater also. But M. Pelletieau has not taken into account the fact that this holds true only for the extreme outside particles of the section. Thus, referring back to Fig. 1, we see that if for the curve P A S, which represents the edge of the body, we substitute another of greater curvature $P^1 A S^1$, then the unbalanced part $Q B R^1$ within the circle of action is greater, and not less than it was before, and the attraction which it exerts will be greater also. It is true as M. Pelletieau points out, that the whole attraction upon M is less than if it were close to the edge at A, but this does not apply to the difference between the attractions in the two cases, which is what we are concerned with here. It is only when M is so close to the surface that the two curves P A S, Q B R, cut each other some distance within the circle of action, that the opposite effect is produced. It might thus seem probable that the resistance to crushing, instead of being diminished, is increased, by diminishing the radius of curvature. In point of fact, however, all such variations may be neglected on account of the excessive smallness of the circle of action as compared with the circle of curvature, whatever the size of the latter may be. This in all cases makes P A S so very nearly a straight line that the differences of area cut off by it in various cases are insignificant compared with the whole area of the circle of action. Thus the truth seems to be that the resistance to crushing will practically be the same for any form of cross section, provided it be bounded by curves. In the case of sharp angles it is more difficult to come to a decision. The opposing lines P A S, Q B R, in Fig. 1, will then cut each other within the circle of action much sooner than before, and therefore the attraction will decrease with the angle (M. Pelletieau's principle) in particles further within the surface, than where the boundary is a curve ; but on the other hand, the unbalanced attraction on a particle some way within the surface, such as M in Fig. 1, will be larger. Putting one of these against the other, as without further knowlege of the laws of cohesion it would be impossible to make an exact calculation, we may consider that in the case of an angular, as in that of a curved section, the form will have no appreciable influence on the crushing strain.

The third and perhaps most important of M. Pelletieau's rules, as stated above, must therefore be held to be incorrect. It remains to consider in order the other four. The first asserts that the resistance to crushing will be greater as the friction between the prism and the plane on which it stands is greater. Thus, supposing the plane to be perfectly smooth, the prism will begin to crush at its base, both because the base has to support the weight of the prism itself as well as the superimposed load, and also because the distension produced by compression is there resisted by the forces on one side only of the section, since there is no cohesion between the plane and the base. If, on the other hand, the base were absolutely fixed and embedded in the plane, it would be impossible for crushing to commence there, and the prism would bulge and crush at some intermediate point between the top and bottom, which would clearly require a considerably larger compressive force. Where the prism is not fixed to the plane, but there is friction between them, intermediate effects will be produced, the prism will still crush at the base, but will require a greater force to do so, since the distension will be to some extent resisted by the friction of the plane.

M. Pelletieau's second rule is that the resistance is greater as the plane is more flexible, that is, yields more under the pressure. He bases this on the supposition that under the pressure the plane will deform into a curve, as shown in Fig. 3, and that the reactions between

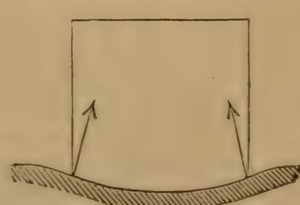


FIG. 3.

this and the base will be normal to this curve, and therefore incline inwards round the edge of the prism, as shown by the arrows. The inward action of

these reactions he considers would resist the distension of the base due to the compressive force, and the greater the deflection of the plane, and therefore the inclination of the normals to the vertical, the greater this inward action will be. But this conclusion would seem to be incorrect for two reasons. In the first place, the inclination of the normals to the vertical would in all practical cases be so small that the resulting inward action could not but be inconsiderable. And secondly, that the action between two surfaces is normal to them, is by no means a universal rule, and in any case only holds good with regard to perfectly smooth surfaces, which these are not. The flexibility of the plane cannot, therefore, be considered to have any effect on the resistance to crushing, provided, of course, that it is not so soft as to crush itself before the prism does so.

The fourth rule—viz, that the resistance will be greater as the absolute size of section is smaller—is founded on the same principle as the rule last considered, and therefore falls with it. It is obvious that with very small sections the reverse will hold, as the narrower the prism the more liable it is to yield by cross breaking.

M. Pelletieau's fifth and last rule is, that the crushing strain is less as the height is greater. He cannot be supposed to mean that the strain varies in proportion, so that a prism 1 ft. high would only bear half the load of one whose height was 6 in.; for this would be against all experience. All that can be understood is, that the crushing strain will be to some extent less in the former case than in the latter. Even this does not agree with the principle generally assumed, which is that the crushing strain is independent of the height, unless the latter be so great that the prism becomes what is called a "long pillar," and is liable to yield by cross breaking. It is probable that this is not absolutely correct, and that even with short pillars the resistance to crushing is to some extent affected by the height. Mr. Eaton Hodgkinson found this indeed to be the case with substances which yielded by shearing, or the sliding of one part over another; but this is not the kind of crushing considered here. No sufficient experiments appear to have been made, at least in England, upon this point; and all that can be said at present is, therefore, that when the height is considerable—say more than five times the thickness—it is as well to take a somewhat enlarged factor of safety.

It appears, then, that M. Pelletieau's five rules, as given above, cannot be accepted as correct. On the contrary, neither the flexibility of the base, the form of the cross section, or the absolute size of prism, can be supposed to exercise any effect on the crushing strain. It is true that this may be expected to be larger as the friction of the base is greater, and also as the height of the prism is less; but in neither case is the variation large enough to be of much practical importance. Hence, the ordinary rule, which makes the resistance to crushing, in any given material, proportionally simply to the area of the block, may still be accepted as substantially true, at least until some exhaustive series of experiments or some more searching analysis shall prove the necessity of its modification.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—A communication from George W. R. Bayley, of New Orleans, dated March 31st, enclosing profile of South Pass bar, showing progress, to that date, of improvement at the mouth of the Mississippi, and one from James B. Francis, of Lowell, Mass., of the same date, referring to the failure of the dam of the Leicester reservoir of the Worcester Water Works, were read. Sketches accompanying the latter were examined, and an account of the failure was given, by John T. Fanning, of Manchester, N. H.

Discussion of "Notes and Suggestions on the Croton Water Works and Supply for the Future," was taken up. A communication from James B. Francis, dated April 3d, and one from J. Herbert Shedd, Providence, R. I., dated April 4th, were read; the discussion was continued by Francis Collingwood, J. James R. Croes, Benjamin S. Church, Alfred W. Craven, Julius W. Adams and George S. Greene.

Robert H. Thurston made some remarks upon the peculiarities of the two classes of metals referred to, in a "Note on the Strength of Materials as affected by Time," presented to the Society; and illustrated them by exhibiting typical strain diagrams, obtained by plotting the results of experiments on transverse strength, which were in progress at the Mechanical Laboratory of the Stevens Institute of Technology.

A bar of each class was represented, one of

which exhibited the exaltation of the elastic limit under strain, while the other exhibited depression of the elastic limit and flow. A third bar was very elastic and brittle, and exhibited both flow and the depression of the limit of elasticity.

He next took up the subject of railway traction, and referred to the Dudley dynograph as a means of determining the same, illustrating his remarks by exhibition of the graphic record obtained by use of this instrument.

After consideration of the two subjects, the following were offered—and under the By-Law adopted January 5th, referred to the Board of Direction :

Resolved, that a committee of three be appointed to examine and report upon the recent failure of the dam at Worcester, Mass., the same to be without expense to the Society.

Resolved, that a committee of five (*named in resolution*) be appointed to examine and report upon the resistance of railway trains ; such to be without expense to the Society.

April 19th, 1876.—A stated meeting was held at 8 o'clock P. M.

Robert L. Cooke, C. E., of New York, read a paper, giving the "History of the Lehigh Coal and Navigation Company, and its Works."

The discussion of "Notes and Suggestions on the Croton Water Works and Supply for the Future," was continued from the last meeting ; communications from William R. Hutton, dated April 6th, and William J. Mc Alpine, dated April 18th, were read, and further discussion was postponed to May 3d.

CIVIL ENGINEERS' CLUB OF THE NORTHWEST. —REPORT OF APRIL MEETING.—The 65th regular meeting of the Club was held at the Sherman House Club rooms on Tuesday the 4th inst., beginning at 4 o'clock P. M ; President Chesbrough in the chair and a large attendance of members, including several non-residents. After the approval of the minutes of the last meeting the following persons were elected members : A Case, 38 Portland Block, Chicago ; G. F. Kirby, 420 Fifth Avenue, Chicago ; C. J. Roney, Chicago University ; Henry Stewart, associate editor *American Agriculturist*, New York City ; W H. Newton, Chicago. Mr. Greeley read a partial report of the Committee on the Adoption of the Metric System of Weights and Measures, which was accepted and the Committee continued. By request of the President R. J. McClure, C. E., of the C. B. & Q. Ry. was added to the Committee, and on motion it was resolved that the next regular meeting be set apart for the discussion of the Metric System. Papers by C. J. Quetil, C. E., of Camden, N. J., and by W. Sooy Smith, C. E., of Maywood, Ills., were read, and that of Mr. Quetil on the "One Rail" system of railway was discussed by Chas. Paine, Past President, President Chesbrough, the Secretary, and other members.

IRON AND STEEL NOTES.

RAILWAY IRON TRADE OF GREAT BRITAIN.— The additional experience which each month supplies as to the course of our export iron trade this year cannot be said to be favorable. Thus, our exports of railway iron have been as follows in the first three months of the last three years :

Month.	1874.	1875.	1876.
January . . Tons	46,598	36,171	23,580
February......	49,713	35,086	18,099
March	62,992	31,369	21,939
Total........	159,303	102,626	63,618

It will be seen that the total supplied by the first quarter of this year was not half so large as that for the first quarter of 1874, and that our foreign iron trade relations are just now distinguished by what an Irish statistician once described as a "progressive decline of prosperity." The collapse in the demand for our railway iron in the United States is now almost complete, and it is certainly disheartening in the last degree. In the three months ending March 31 this year we only sent the Americans 85 tons, while our corresponding exports in the same direction, in the corresponding period of 1875 were 9013 tons ; and, in the corresponding period of 1874, 28,025 tons. The colonial demand has attained during the last year or two a compensatory importance, but even this resource appears to have failed our industrials this year to some extent. Thus, the exports of our railway iron to British America, British India, and Australia have been as follows during the first quarters of 1876, 1875, and 1874.

	1874.	1875.	1876.
British America . . Tons	374	6,221	2,083
British India..........	13,172	10,015	11,497
Australia.............	20,051	22,583	8,245
Total...........	33,597	38,819	21,825

We have been sending a little more railway iron this year to Sweden and Norway, as well as to Spain and Italy ; but the collapse of South American credit has had the effect of materially contracting our deliveries of rails to Brazil, Peru, and Chili. These deliveries have moved on as follows to March 31 in each of the last three years :

Country.	1874.	1875.	1876.
Brazil. . Tons	5,796	2,678	3,990
Peru.........	2,008	9,832	1,644
Chili.........	4,170	5,650	631
Total......	11,974	18,160	6,265

In fact, in almost whatever direction we turn we find our export railway iron trade a prey at present to depression and gloom. What with a reduction in the aggregate amount exported, and the great decline which has taken place in the price of rails during the last few months, the aggregate value of our railway iron exports in the first quarter of this year did not exceed £576,904, as compared with £1,057,135 in the corresponding quarter of 1875, and £2,133,514 in the corresponding quarter of 1874.

It appears to us, however, that although the reduction in the price of rails may cause our iron trade statistics to present a discouraging appearance this year, it contains important elements of future hope. Thus, even assuming

that the American market is hopelessly lost—and if it is so lost, the fact is undoubtedly a great misfortune to the British iron trade—the apparent possibility of once more delivering English rails upon cheap terms and conditions must be a highly important condition of future prosperity. If we can send our rails at a cheap rate to British India, Canada and Australia, the authorities and capitalists of those important dependencies will certainly be induced to infuse a litttle additional vigor into the works of railway construction, and an increase will be witnessed, in consequence, in the Indian, Canadian, and Australian demand for our railway *materiel.* Not only will such an increase be witnessed, but the development of anything like colonial competition in the matter of railway iron will also become a task of greater difficulty than ever. It is not enough that our ironmasters should now be selling rails at a comparatively cheap rate. They must be able so to sell them, and to still retain a profit upon their industry and enterprise. The question is —"Are the current conditions of the iron trade favorable to the attainment of this result?" We incline to think that they are. Labor is cheaper, coal is cheaper, and foreign iron ore is also becoming more abundant. The very troubles and disasters which have weighed down our iron trade for many weary months appear to have brought with them some compensatory conditions. The cloud of adversity has had a silver lining after all. But still we cannot overlook the fact that our foreign railway iron trade has lost so much ground of late years that even the process of recovery must extend over a considerable period.

RAILWAY NOTES.

Prussian Railways.—It is computed that Prussia has now 11,000 miles or thereabouts of railways, which have cost in round figures £210,000,000. In 1870, the amount of capital expended upon Prussian railways did not exceed £125,000,000 so that the additional capital to the amount of £85,000,000 has been laid out during the last five years. It is not to be wondered at, under these circumstances, that Prussian railway enterprise now appears to be flagging. The aggregate receipts have scarcely kept pace with the work of construction.

The Pneumatic Railway in Paris.—The "*poste atmosphérique,*" for the despatch of messages between Paris and Versailles, has just been completed, and is nearly thirteen miles and a half in length. The tubes, which are made of brass, are 13 ft. long, 3½ in. in diameter, and ⅜ in. thick, are laid at a depth of 8 ft. from the surface, on a flooring of wood, and are pitched both inside and out. The route outside the walls of Paris is along the highway "No. 10." Inside the city they are suspended in the sewers. At the Bridge de l'Alma the tube bifurcates, one portion passing to the Palace de l'Elysee, the other to the Central Telegraph Office. At Versailles the terminus is in the new hall now being built on the left wing of the palace.

An English paper says: Russian engineers are learning to economize. They are not, as heretofore, sending their old rails to this country as such; but they are keeping them at home, and are sending to this country for iron in a partially manufactured state, with which to utilize the old rails in transforming them into new. Blooms are now being made in the Cleveland district, to be used in tops as single, or as tops and bottoms in double-headed rails, in connection with the old rails, which will be employed as the centre of the new rail. The slabs are cut to lengths suitable for the piles built up of the old rails, and they are being made of a quality of iron of extra hardness. Perhaps 600 tons of these slabs are sufficient, with the requisite old rails, to make 2000 tons of new rails. The economy, therefore, which the Russian engineers are adopting, tells upon the demand for rails for Russia, which was previously expressed by existing companies at the iron works of this country.

New Car Ventilator.—The Winchell car ventilator, which has been on trial for some time on the Cincinnati, Hamilton and Indianapolis Railway, consists of an air-chamber attached to the roof of the car and extending its entire length. Each end is furnished with a hood, protected by very fine wire gauze screens, through which the air, and nothing else, is admitted to the chamber. Each drum is furnished with a cut-off, operated by a lever within the car, by means of which the supply of air may be regulated. A number of registers in the bottom of the chamber admits the air to the car. When the train is in motion the cut-off in the forward end of the car is opened, and the air enters, passes down through the registers, enters into the car, and, having served its purpose, makes its exit through the rear hood or through the windows, if they are open. In connection with the air-chamber, and for summer use only, are deflectors on the outside of each window, whose purpose is to act as an exhaust, and not only draw out the impure air from the car, but prevent the admission of smoke, dust, cinders, and rain through the open window. These deflectors, which are made of glass, so as not to impede the view from the windows, are operated simultaneously by means of an iron rod running along the side of the car.

New Railmaking Experiment. — At the Wyandotte Rolling Mill, at Wyandotte, near Detroit, Michigan, recently, railroad rails were made of iron base and Bessemer steel head, so successfully welded that the most trying tests failed to show even the point of the juncture of the two metals. The same experiments showed the welded rail even better than the solid Bessemer steel. Each was submitted to sixty blows by a 20-ton hammer. The Bessemer rail was completely shattered, cracked through and through in every direction; the welded rail, though mashed down and twisted in the neck, showed no sign of a fracture in any part.

The *Detroit Post* says, this feat was accomplished by the use of a peculiar metalloid sponge or flux in the following manner:—The

pile is made up as for the ordinary iron rail. For the head, scraps of steel, hitherto not used at all, are spread of the desired thickness, and upon this is laid a plate of steel. The flux, in the shape of hard substance about the size of a kernel of corn, is scattered through and over the pile, which is then placed in the oven. When properly heated it is drawn and rolled in the ordinary manner. It is found to be a perfect homogeneous mass; the fibrous iron and the crystalline steel having their particles so interwoven that it is a physicial impossibility to separate the one from the other. Breaking or twisting does not produce a separation at the point of juncture. The wonderful work of uniting iron and steel, so mechanically different, into one homogeneous mass, is accomplished by this peculiar flux, which is composed of fifty-five parts of iron, twenty parts of silicon, and twenty-five parts of aluminium. The chemical action of these substances is explained to be as follows:—The silicon takes up all the alkaline matter, while the aluminium eliminates the free oxygen, phosphorus and sulphur, thus making a uniform, constant, close-grained metal.

ENGINEERING STRUCTURES.

Modern Engineering Feats and Fancies.—The present century has witnessed several remarkable achievements in marine engineering, such as the drainage of extensive arms of the sea in Holland, the construction of the Suez Canal, and the deepening of the estuary of the Mississippi; and, not content with these, still more gigantic schemes have been projected. It has been proposed to admit the Mediterranean into two extensive tracts of the Sahara, which would give water communication to a large portion of Algeria, and make a seaport of Timbuctoo. Neither plan is likely to be put speedily into execution; but in the meantime Mr. Spalding, an American, comes to the front with a proposal to turn the waters of the Black Sea into the Caspian, thus enlarging the latter to its pristine size, and turning the barren and almost impassable deserts left by the subsidence of its waters into a highway of commerce for Central Asia. This ancient sea basin is considerably depressed below the general ocean level, and has been silted up in the course of ages by the Ural, Volga, and other lesser streams which flow into it. The consequence of this contraction and shallowing of the Caspian has been, not only that the land left dry is incurably barren, but that the surrounding country has become unfruitful from want of rain, consequent on the diminished evaporation. Mr. Spalding proposes, as we have said, to restore to the Caspian its ancient body of waters, its ancient depth and area, which was nearly double its present extent, by connecting it with the Black Sea by a channel 150 miles in length, about 170 yards wide at its eastern extremity, but two-thirds narrower on the western half. The projector calculates that at the end of forty years from the beginning of the work, the level of the two seas would be so nearly uniform that the navigation of the new channel could begin. Mr. Spalding further proposes to join the Don to the Volga, and thus lay the sea of Azof also under contribution. The mere excavation of the proposed canal does not seem very difficult, and as the Russian Government appears to have directed its attention to the scheme, doubtless the opinion of competent scientific men as to its feasibility will be obtained. If it should prove successful it would be a magnificent work, and followed by political and economic results more than commensurate with the skill and outlay that would be required for its completion.

The Manora Breakwater, Kurrachee.—The Manora Breakwater was the most important feature of the Kurrachee Harbor Works, which were commenced in 1860, from the designs of the late Mr. James Walker, Past President Inst. C. E., assisted by Mr. William Parkes, M. Inst. C. E. Besides the breakwater the chief works were—in the lower harbor—a stone groyne 8,900 feet long, dredging and removal of rock, and—in the upper harbor—an increase of one-fourth to the area of the backwater, involving a new tidal channel 2½ miles long, crossed by a screw pile bridge 1,200 feet long, and an embankment 2,780 feet long, to close the old channel, also of a jetty 1,400 feet long with quays. All these works are now nearly completed, and have already produced great benefit, the entrance having been made direct instead of circuitous, deepened 6 feet and sheltered, the anchorage space enlarged, and the internal accommodation improved. The trade of the port was 3½ millions sterling per annum, and railway communication with the Punjab would further develop it. About £450,000 had been expended on the whole of the harbor improvements.

The breakwater projected from Manora Point for a length of 1,503 feet into a depth of five fathoms of water, in order to shelter the entrance from the south-west monsoon seas, and to prevent their tearing up sand from the bottom and depositing it as a bar. The characteristics of the sea, wind, and tides, as bearing on the design, were alluded to, and it was stated that the bottom was irregular near the shore. The structure consisted of a base of rubble stone, levelled off generally to 15 feet under low water, and on this base, concrete blocks, each weighing 27 tons, were set on edge, leaning back at a slope of 3 inches to 1 foot, and without bond, two blocks forming the width and three the height, and together making a square of 24 feet in cross sections, the top being about the level of high water. The rubble base was deposited from native boats, and was levelled for the superstructure by helmet divers. Two European mason divers were employed, and six native divers trained on the work, the latter chiefly for shifting the rubble. No accident occurred, and the party generally did not suffer in health. After mentioning circumstances which determined the use of concrete blocks and of Portland cement, particulars were given of the composition of a 27-ton block, the materials being cement, river sand, shingle, and quarry lumps, with saltwater. The ratio of the bulk of the

cement to that of the finished block was nearly $\frac{1}{11}$. About 3,500 tons of cement were used, costing from £3 17s. to £4 10s. per ton. The mixing station, block ground, and moulding of the nineteen hundred and seventy-two blocks, including three hundred and twenty-five of special smaller sizes, were then described; and it was remarked that the "Messent" mixers had been found very efficient. The blocks were sometimes used one month after being made, and once, as an experiment, a 27-ton block was safely lifted in seven days. When the work was fairly established the blocks cost for current expenses 15s. per cubic yard, though the average total rate was raised beyond this by extra expenses in the earlier stages.

The blocks were lifted on to the trucks by a steam hydraulic traveling crane of 50-feet span; each truck carried one block, and was taken separately by a tank locomotive to the breakwater. The blocks were set by a steam traveling crane, called the "Titan," which ran on rails laid on the finished work, and overhung the end, so as to carry the blocks of three tiers in advance to their places, thus dispensing with staging. The framing of this crane supported a traveler and crab, worked by an eight-horse power engine on the top, which also drove the traveling gear of the entire machine. The cost of the Titan, delivered and erected at Kurrachee, was £2,879. The rate of setting was limited by the progress of the foundation and by the supply of blocks, but during the last season ten 27-ton blocks were set daily on an average, while on one occasion six blocks were laid in one hour and forty minutes without special pressure.

The base was commenced on March 17, 1869; and later in that year the shore end "stump," 45 feet long, to make a starting place for the Titan, with other preparatory works, was completed, after some unavoidable delays, and the first block was set on November 1, 1870. The delays of the foundation were specially felt in the first season's work, but a length of 225 feet was built in four months, taking the breakwater out to 270 feet from the shore. During the second season, 1871-72, after a few days spent in repair of monsoon damages, a length of 523 feet was built in about four months, making a total of 793 feet. During the third season, after the repair of monsoon damages, a length of 710 feet was built, completing the breakwater on February 22, 1873, to its full length of 1,503 feet, which had thus been barely twelve months in actual building.

The action and effect of the monsoon sea, and the repair of damages were then detailed. In 1871 the center joint opened here and there, and one block was washed over from the top course on the harbor side. Slight damage also occurred to the shore end in the sea angle. The nature of the settlement was described, also a curious rocking action, and the closing up of the cross joints under the action of the sea. The repairs of the damage, in the first season, cost £185. During the second monsoon, 1872, twenty-five blocks were washed out from the top course on the harbor side, eighteen of these blocks being in one length of 86 feet. The damage was again traceable to inequality of settlement. The sea side did not suffer, nor did the shore end, though both showed evidence of the force of the sea. The damage was repaired in a few days at a cost of £512. The monsoon of 1873, the first after the completion of the breakwater, did trifling damage, and was confined to the shore half length, still pointing clearly to weakness of foundation. The repairs cost £199. In the monsoon of 1874, the outer end and "scar," which had not then been in any way specially secured lost five blocks during unusual weather, though no other part of the outer half length suffered, but the shoreward half opened here and there. The repairs of this season cost £418 and included the re-erection of an iron beacon on the outer end. The nature and extent of the subsidence (which in some parts amounted to 3 feet, but without dislocation), were then noticed, and the action of a mollusk, the "Pholas," on the concrete blocks, also the effects of the sea on the rubble base, which did not, however, affect the stability of the superstructure.

The cost of the breakwater had been £93,565 or £62 5s. per lineal foot, but this amount included preliminary charges, the current expenses during the last season being only £34 per foot. This sum included the repair of damages during the progress of the work, and during the two monsoons since its completion, but not the expense of engineering and office establishment. The work had been carried on in the Bombay Public Works Department by the Author and his assistants, advised by Mr. William Parkes, M. Inst. C. E., as Consulting Engineer, and without the employment of any general contractor. The completion of the work was favorably noticed by all the Government authorities concerned.

ORDNANCE AND NAVAL.

IRON SHIP CONSTRUCTION.—The following is the substance of the paper read by Mr. De Rusett at the late meeting of the Society of Naval Architects, relative to the longitudinal girder or bulkhead system of iron ship construction patented by Messrs. C. Chapman and E. W. De Rusett.

The reader of the paper said the patentees attributed some of the calamities to long steamers to weakness in construction, especially as the losses of unclassed vessels are nearly twice as numerous as those which are classed, and they say, "our opinion is confirmed when we have the results of the elaborate calculations of Mr. Johns before us, showing that first-class vessels of 3000 tons and upwards, built to Lloyd's rules of two or three years back, when poised on the crest of a wave equal to the vessel's length, have only a margin of safety of 2½, which is not half of that considered necessary for structures on land, such as bridges, &c., which have no such variable loads as a ship has to bear, neither are they subject to the sudden additional strains of immense masses of water heaped on them, or the violent blows from giant ocean waves, or the terrible vibration of the huge screw when the vessel pitches heavily before an Atlantic swell." The patentees endeavor to show that a vessel

may be so constructed that she would be, as compared with others now in use, nearly unsinkable ; and in order to make it clear that such a vessel can be constructed it will be necessary, in the first place, to show how a greater strength can be obtained without making the vessel more costly and heavier. "An iron vessel of 3000 tons is only a quarter as strong as an iron vessel of the ordinary kind whose tonnage is 100, and a vessel of 3000 tons is only half as strong as a vessel of 1000 tons. The above are mentioned as examples to set people thinking about the respective strength of large and small vessels ; and having given a little thought to the matter, they will naturally say to themselves, 'Why are the large vessels not built stronger ?' The answer to that is that they cannot build them much stronger without making them so heavy and so costly that, commercially speaking, they would be failures—that is to say, if they continue to build them on the present principle of construction. Therefore, before a vesssel can be built at anything like the same price to be very much stronger, and without additional weight, something new must be added to her in some particular part of her that will give greater strength—in fact it must be put in such a position in the vessel that it will admit of the taking away of great weights from other parts, so as to bring the weight of the vessel to what it would have been had she been built in the ordinary manner." The plan submitted to the meeting was as follows :

"We lay the keel of the ship down exactly as if were going to build an ordinary vessel. After the keel is laid, we place a sheet of iron on one side of it—say the port side—and this sheet runs down to the bottom of the keel, and is drilled for riveting to it. This sheeet of iron runs right fore and aft the keel, and is riveted to both the stem and the stern post, and rises perpendicularly, right in the midships of the vessel. The first plate of this longitudinal bulkhead having been placed by the side of the keel, both sides of the vessel's bottom may be placed just the same as if there had been no alteration in the construction of the vessel whatever. With respect to the shape of the vessel's bottom, there need not be the slightest alteration in it, nor need there be any alteration in the weight and strength. After dividing the vessel into two parts by means of the longitudinal bulkhead, the vessel is again subdivided into nine compartments, which give the vessel in all eighteen compartments, and each of these latter is really strong enough to hold on against the pressure of the water—they are, in fact, as strong as any other part of the ship. Therefore, assuming that four vessels ran into her at one time, say two on each side, she will not sink, not even if she gets the hardest knocks that one ship gives to another under such circumstances. There is the same degree of safety to life when this type of ship gets on shore ; it will take four times the strength or force of the ocean waves to break this vessel up than it would to break up an ordinary vessel. Again, should a fire break out on board of this class of ship, any of the compartments where the fire was raging might be at once flooded without the slightest danger of sinking the ship."

The patentees advocate twin screw propulsion, as advocated by Capt. T. E. Symonds in 1862, and others, and now generally adopted by Her Majesty's Government in the largest ironclads, as well as gunboats, and applied to merchant ships. Among the former may be mentioned the *Invincible*, *Iron Duke* and the *Vanguard*, all vessels of 6000 tons and about 4800 indicated hore-power ; and also the *Thunderer*.

Austrian Ironclads.*—Having recently had occasion to ask my friend, Herr Romako, the chief constructor of the Imperial Austrian Navy, for some particulars of certain ironclad vessels designed by him, I have thought it would be useful to the members of this institution if I placed an outline of the same before them.

The first ship which I propose to mention is the new ironclad *Tegetthoff*, now under construction at the works of the Stabilimento Technico, at Trieste. This large establishment took the contract for the hull, engines and boilers in August last. The following figures give her dimensions, calculated elements, &c. Length between the perpendiculars, 286 feet 11¼ inches ; length, total, 303 feet 1¼ inches ; breadth on the water-line, 62 feet 9 inches ; extreme breadth to the outside of armor, 71 feet 1½ inches ; depth of hold, 34 feet 9 inches ; draught of water, aft, 26 feet 7½ inches, draught of water, forward, 23 feet 1 inch ; displacement with the half of provisions, 7390 tons ; area of the midship section, 1301 square feet ; area of the load water-line, 14,308 square feet ; height of metacenter above center of gravity of displacement, 14.623 feet ; height of metacenter above water, 4.770 feet ; distance of the center of gravity of displacement before the midship section, 3.356 feet ; depth of the centre of gravity of displacement below water, 9.853 feet ; coefficient of displacement, 0,582 feet ; co-efficient of water-line, 0.782 feet ; co-efficient of midship section, 0.82 feet ; displacement of an inch immersion at the load water-line, 34.47 tons ; weight of armor and backing, 2160 tons ; the armament consists of six 11-inch Krupp guns. Area of sails, 12,165 square feet ; cost of hull, estimated, £172,790 ; cost of engines and boilers, estimated, £81,715 ; nominal horse-power, 1200 ; number of cylinders, two ; diameter of cylinder effective, 125 inches ; length of stroke, 4 feet 3 inches ; Griffiths propeller, diameter 23 feet 6 inches ; pitch 24 feet ; number of blades, two ; revolutions per minute, seventy ; number of boilers, four; area of fire-grate, 850 square feet ; heating surface, 25,500 square feet ; superheating surface, 1800 square feet ; pressure of steam, 30 lbs. ; number of furnaces, thirty-six ; mean indicated horse-power, 8000 ; speed, estimated, fourteen knots.

From these figures it will be seen that although we are not dealing with a ship of the *Inflexible* (English) or of the *Dandolo* (Italian)

* Mr. E. J. Reed, before Naval Architects.

type, in which armor of excessive thickness is placed over a central citadel of extremely limited extent, we, nevertheless, have a very powerful ship indeed, with armor of apparently about 13 inches to 14 inches thick, and with a concentrated battery of six 11-inch Krupp guns, each weighing, I presume, about 27 tons. The ship has a belt of armor extending from the stern to within about 30 feet of the foremost perpendicular, where it terminates in a transverse armored bulkhead, and a stout iron deck going forward to the stem at about 7 feet below water.

In this ship the Austrian Admirality have adopted an improvement in armor to which I have for a long time past attached great importance—I refer to the getting rid for the most part of great curvature. Of course armor-plates, if carried round the ends of a ship, must be bent to the curvature of the water-lines, and when embedded so to speak, in the sides of a ship of ordinary form and curvature—as has been usual in sea-going ships—they must also be bent crosswise. Now this double curvature of the plates is not only an expensive process, but it is also injurious to the armor-plates in some degree. To foreign Governments which do not make their own armor-plates, and especially to the Governments of countries very remote from England, the system will further be attended by extreme difficulty in replacing plates injured in battle. This could hardly be accomplished by the slow and expensive process of sending accurate moulds to England for the guidance of the manufacturers. By so designing the ships that the armor-plates have only to be curved in one direction, all these disadvantages and difficulties are practically got rid of, and therefore, in recent ships which I have had occasion to design for foreign Powers, I have carried out this principle, and Herr Romako, in a letter to me, says:—"With your encouragement I have undertaken to give the stern a form which enables the bending of the plates to be performed in only one way."

The next feature to be remarked in this ship is that the battery is of the projecting type, which so greatly facilitates the obtainment of direct fire ahead and astern from a midship battery without excessive recession of the unarmored parts of the ship before and abaft the battery. The Admiralty constructors and myself introduced this arrangement in many cases of upper-deck batteries in ships designed while I was at the Admiralty (most notably in the case of the *Audacious* class), but I do not think the same thing has been done at the Admiralty in the case of the main-deck battery. I have, however, done it myself in several ships for foreign Governments, such as the *Kaiser* and *Deutschland* (German), and the *Almiranti Cochrane* and *Valparaiso* (Chilian) armor clad ships. In the *Tegetthoff* the overhang is very low, and considerable in amount, the battery projecting between 4 feet and 5 feet, the spread commencing at 18 inches above the water, and terminating at a height of 6 feet.

A still more novel feature, one which, although I have seen it suggested before, has never before, to my knowledge, been carried out. It consists in depressing the sides of the ship into curved indentations in wake of the guns. The object mentioned to me by Herr Romako, as that which has been sought in the arrangement, is the protection of the gun-muzzles. In mentioning the general form of the battery, and more particularly this feature, he says: "The ship *Tegetthoff* is in many regards a novelty, its casement allowing an all-round fire, avoiding at the same time, by its particular form, the dangerous projection of the muzzle of the midship guns, in consequence of experiences acquired in the battle of Lissa, but which are very little known even in our own navy."

The *Tegetthoff* is also to be furnished with a transverse bulkhead abaft the foremost gun, an arrangement which will prevent the battery from being raked in chasing. This improvement exists in the *Alexandra*, where it was, I believe, introduced for the first time by the present Admiralty constructors. The foremost bulkhead of the battery is inclined forward at a considerable angle to within about 4 feet of the middle line, where it becomes transverse. Immediately over this foremost portion of the battery at the middle is a very strong pilot tower, standing well up above both the gunwale and the forecastle. This shows that the Austrian officers, who have been in an action with ironclads, do not consider such towers unnecessary.

It may be interesting to add that while the outer skin and angle irons of the hull are of iron, all the remainder is of Bessemer steel, varying in tensile strength from 30 to 33 tons per square inch of section, and possessing this, as I am informed, in combination with 25 per cent. of ductility. This Bessemer steel is produced very successfully in Styria and Carinthia, from which districts of Austria the chief supplies for the *Tegetthoff* are derived.

BOOK NOTICES.

THE THEORY OF SCREWS. By ROBERT STAWELL BALL, LL.D. Dublin: Hodges, Foster & Co. For sale by D. Van Nostrand. Price $5.25.

The sub-title to this work is, "A study in the dynamics of a rigid body." This explains the scope of the work much better than the first one.

Students who are fond of working in the field of the higher theoretical mechanics will read the work with satisfaction, but no others will.

POCKET-BOOK OF USEFUL FORMULÆ. By G. L. MOLESWORTH. London & New York: E. & F. N. Spon. For sale by Van Nostrand. Price $2.00.

This is the eighteenth edition of this compact and convenient little pocket-book. It has been gradually enlarged in the later editions, and the older portions improved by the elimination of the errors of typography, which are incidental to first editions.

The present edition is more than double the size of the first one. It has been increased from 220 to 592 pages.

Among the later additions, we notice a short synopsis of methods of the calculus, and some thirty pages devoted to telegraphic engineering.

A SHORT HISTORY OF NATURAL SCIENCE. By ARABELLA B. BUCKLEY. New York: D. Appleton & Co. For sale by D. Van Nostrand. Price $2 00.

If this book is what it appears to be to such brief inspection as we have been able to subject it, it deserves a place in every library, and is indispensable to every school library.

A history of the rise and progress of scientific labor, with plain descriptions of early methods of research, and carefully compiled chronological tables, is certainly something desirable to have, and is nowhere else attainable that we know of.

The style is agreeable, and the illustrations, though few, are well chosen. Although written for schools and young persons, old persons out of school will read it with pleasure and profit.

THE ART OF FURNISHING ON RATIONAL AND ÆSTHETIC PRINCIPLES. By H. J. C. London: Henry S. King & Co. For sale by D. Van Nostrand. Price $1.75.

The subject upon which this little book treats has lately attracted much attention. There is abundant evidence in the new forms of furniture that the popular interest in the matter of tasteful home decorations is steadily increasing.

Mr. Eastlake's "Hints on Household Taste" did, and is yet doing, good service. The present volume is much less pretentious, and affords general rather than precise hints to the reader. It is divided into two parts; the first treating of Decorations, the second of Furniture, and each part is divided into chapters, devoted separately to the hall, dining-room, drawing-room, library, etc., etc.

The book is easy reading, without illustrations, and we doubt not will prove widely useful.

THE SANITARY DRAINAGE OF HOUSES AND TOWNS. By GEORGE E. WARING, Jr. New York: Hurd & Houghton. For sale by D. Van Nostrand. Price $2.00.

This work is designed to diffuse a better general knowledge of the subject of drainage than can be obtained from any other than professional works. It is free from technical discussions, but covers the ground quite completely.

It contains just the knowledge needed by the young engineer who must know the general principles which underlie his future practice.

It is calculated, moreover, to stimulate town authorities to a better performance of general sanitary work, by clearly setting forth their duties.

The contents herewith appended exhibit the range of topics:

The Sanitary Relations of Drainage; The Drainage of Houses; The Drainage of Towns; Arranging Plans for Town Sewerage; The Construction of Sewers; The Details of House Draining; The Dry Conservancy System; Vaults and Privies; Liernur's Pneumatic System; The Disposal of Sewage.

Thirty-one woodcuts illustrate the text.

DESIGN AND CONSTRUCTION OF DOCK WALLS. By J. ROMILLY ALLEN. London and New York: E. & F. N. Spon. For sale by D. Van Nostrand. Price $2.50.

The present work covers only the subject of *designing* dock walls; the second portion, soon to follow, will be devoted to the more practical part of construction.

The author has logically developed his subject, beginning with the considerations of water and earth pressures against a plane surface; he considers next the statical conditions of the wall, and then the direction of the resultant of these forces. Then come walls of different sections, with and without a *surcharge*.

The mathematical work is of an easy kind, and the solutions are to a certain extent graphic in their character.

The subject is an important one, and is clearly enough treated in the present work, although all the material could have been put quite as satisfactorily in a much smaller space.

The typography and diagrams are excellent.

NAVAL POWERS AND THEIR POLICY. By JOHN C. PAGET. London: Longmans & Co. For sale by D. Van Nostrand. Price $5.25.

The principal portion of this work appeared originally in the *St. James' Magazine;* some additions in the way of statistical information have been made to the first articles.

The work is not so much an essay as a comparative statement of the naval armaments of British and foreign ironclad navies.

The table of contents sets forth the following list of subjects for the separate chapters:

Recent Growth of Foreign Navies; Naval Policy; Strength and Distribution of the British Navy; Personnel of the British Navy; Finance; Naval Volunteers and Coast Defence; Our Ironclads; the Inflexible; The French Navy; The Austrian Navy; The Turkish Navy; The German Navy; The Italian Navy; The Spanish Navy; The Russian Navy; The Scandinavian Powers; The Navy of Holland; The Navy of Greece; Brazil, Chili, Peru, Argentine Confederation; Naval Guns; The American Navy; Suggestions; Tables.

The volume is exceedingly well printed. No cuts are given, as the plan of the work requires none.

RAILWAY APPLIANCES. By JOHN WOLFE BARRY. London: Longmans, Green & Co. For sale by D. Van Nostrand, Price $1.50.

This book is the latest issue of the series of Text Books of Science, and is in no way inferior to its predecessors. It is essentially a work for the practical railway engineer. It deals with the lesser details of construction, and with systems of management.

Under the head of "Permanent Way" are described various forms of rails, rail joints, sleepers, chairs and their fastenings, and the action of the wheels on the rails.

Under "Points and Crossings" are treated Safety-points, three throw-points, single-tongued points, slip points, and various forms of crossings.

"Signals" deals with all the various forms of hand, mechanical and electrical signals.

One chapter is devoted to the "Block System," another to "Stations" and includes such adjuncts as turntables, weighing machines, etc.

"Rolling Stock" is a comprehensive subject and occupies corresponding space. Seventy pages are devoted to minute descriptions of cars, wheels and brakes.

Nothing relating to English Railways is left undescribed. Nothing could be better apparently than the methods of description. Over two hundred wood cuts are distributed throughout the book.

MISCELLANEOUS.

Of the 50,707,175 tons of coal mined in the United States last year, Pennsylvania produced 36,547,615 tons, or 72 per cent. of the whole output.

We learn that the sub-Wealden bore is temporarily arrested at 1672 ft. from increasing deposit from the sandy beds. The original problem was dependent on the opinion of geologists that palæozoic rocks would be found at a depth varying from 700 ft. to 1700 ft. So far, however, the strata are mesozoic; but the latest fossils give some indications of a palæozoic rock. Much hope is therefore entertained of solving the problem.

Improvements in Safety-Lamps.—The invention of Mr. A. B. Boullenot, of Paris, consists in replacing the Davy or safety-lamps ordinarily used in mines containing fire-damp by improved lamps supplied with air from outside the mine. For this purpose a fixed pipe or pipes is conducted down the mine, and branches from it are led into all the workings. Compressed air is forced down the pipe by means of air-pumps worked at the surface, and the improved lamps are screwed to the air-pipes where necessary by means of couplings and straight or elbow pipes provided with stop-cocks. The improved lamp consists, first, of a metal air vessel which receives the compressed air, and into the upper part of which an oil vessel drops, fitted with a burner, and a wick (either flat or tubular) which can be raised or lowered by means of a knob outside the lamp. This knob can be disconnected from the oil vessel when it is required to remove the latter. Above the air vessel is cemented a tube or cylinder of glass or crystal, the upper end of which has fitted round it a metal ring carrying a cover formed of two pieces of wire gauze a short distance apart. The glass cylinder is protected by a cage of sufficiently strong metal bars. A reflector is provided carried by a ring fitting round the air chamber and movable into any desired position. Through the center of the gauze cover an opening is left which can be closed by a stopper, and through this openening a light can be introduced consisting of a tube or sheath containing an inner spring clip, which can be raised or lowered by a ring or handle at the top of the tube from outside the lamp. This spring clip carries a match, which can be ignited by rubbing its end upon a rough surface prepared for the purpose at the top of the oil vessel. When the match is ignited the lamp wick is lighted from it, and the match is then extinguished by drawing the spring clip into the tube, which can then be removed from the lamp, the opening in the cover being closed by its stopper; and the lamp will then continue burning so long as the supply of oil and air continues. A valve may be provided in the cover. When necessary this improved lamp may be screwed to a portable receiver of compressed air or oxygen, instead of to a fixed air-pipe.

An Innovation in Roof Construction.—At a meeting of the Manchester Scientific and Mechanical Society, Mr. Grierson in the chair, Mr. E. Grimes read a paper on the above subject.

The author, in the course of his paper, said, recently he had observed that designers of roofs, both architects and engineers, had departed from the old plan of fixing purlins with their upper surfaces parallel with the plane of the roof, and their sides perpendicular to the same, and, instead thereof, had placed them in a position with their sides vertical and their upper surfaces level. He was not quite sure, but he had reason to believe, that engineers first adopted this arrangement and that architects followed suit, presuming, doubtless, that any change made by engineers, who were usually supposed to possess superior mathematical knowledge, could scarcely fail to be right. In his opinion, however, this new mode of construction was incorrect; and, indeed, it would require very little consideration of the forces brought into action in constructing a purlined roof to demonstrate that the practice universally adopted from time immemorial was the mechanically correct one. His attention was attracted to the new arrangement and its results on the occasion of a visit to the Birkenhead Docks. Passing through one of the large coal sheds he observed that the purlins of the roof, which were of timber, (although the principals were of iron), and of great length, were trussed with iron rods and placed vertically. These were in many cases bent considerably by the weight of the roof coming in a horizontal direction, and one or two of them were so much bent that the middle portion of the trussing rods which had been upset and hollowed to form a seat for a large plate stud, were forced aside from their place on the stud to a considerable distance. Looking on the outside of the roof it was at once apparent that there it had sagged, as they termed it, and was a hollow plane. Since that time he had observed several roofs having vertical purlins, and presenting similar results. It appeared to him that the error had arisen from supposing that gravity was the only force necessary to be resisted, in which case, doubtless, the placing a purlin in a vertical position would be the strongest way. This, he contended, was not the fact, the force opposed to gravity coming into play and necessitating the strongest section of the purlin to be placed in a line with the resultant, and perpendicular to the plane of the roof.

The reading of the paper was followed by a discussion in which a general concurrence was expressed in the conclusions arrived at by Mr. Grimes.